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The SCIENTIFIC MONTHLY

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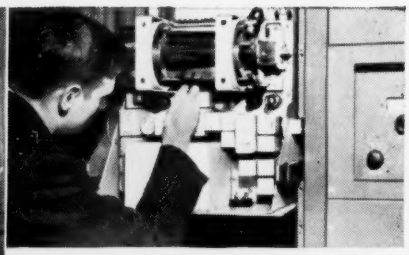

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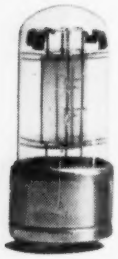

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Science and Technology

(From the Month's News Releases)

New Film

Based on the Land picture-in-a-minute process, a new X-ray technique that results in a finished X-ray picture dry and ready for use in 60 seconds, was demonstrated at the meeting of the Photographic Society of America in October. Exposure is made in the usual way, and the film pack is then run through steel rolls, producing a positive print. No darkroom or especially trained personnel are required. It is expected to be extremely valuable in operating room procedures such as the nailing of fractured hips, reduction of fractures, and the removal of foreign bodies, such as shell fragments. Already tested by the Navy, initial supplies of film will be released to the armed forces early this year.

Stitcher

An electric sewing machine that weighs only 10 pounds sews about 40 feet per minute and is designed to close bales, large containers, and other bulky and hard-to-handle packages of cotton, burlap, paper, and specially processed material of a similar nature. It operates from any 110 v, a.c.–d.c. line, any cycle, and is also available with a 220-v motor.

Publications Noted

Acta Geologica Polonica, Vol. 1, No. 4, October 1950. Quarterly, published by the Muzeum Ziemi, Warsaw (in Polish).

Birds of Montezuma and Tuzigoot. Henry H. Collins, Jr. 16 pp. Illustrations by Roger Tory Peterson. 25 cents. Southwestern Monuments Association, Campe Verde, Arizona.

Chemical Engineering Science, Vol. 1, No. 1, October 1951. Bimonthly. Articles in English, French, or German, preceded by a summary in English and one other language. £4 10*s* per year. Academic Press is U. S. distributor.

The Naturalists' Directory. (36th ed.) $3.00 postpaid. Salem, Mass. Contains names and addresses of amateur and professional naturalists, in addition to a list of natural history museums and scientific periodicals.

The Old Farmer's Almanac, 1952. (160th Anniversary ed.) Robert B. Thomas. 112 pp. 25 cents. Yankee, Inc., Dublin, N. H. Recipes, Anecdotes & Pleasantries, Farmer's Calendar, and 75 other topics are contained in this famous American publication.

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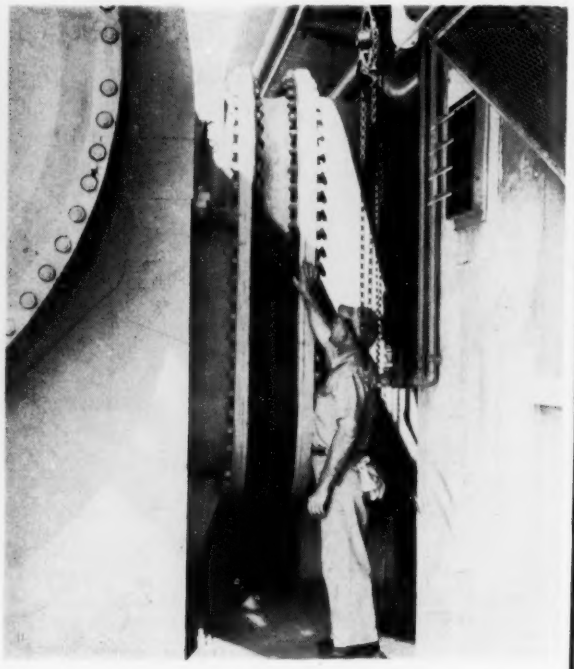

Big rubber and fabric expansion joint installed by U. S. Rubber Company between steam turbine and condenser in Green's Bayou Station of Houston Lighting and Power Co. is 8 feet high, 21 feet wide, and 1 foot face to face. It isolates vibration and supplies a tight seal.

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Chemotherapy for Elms

Seedling elms treated with 2-methylcarboxymercaptobenzothiazole and then inoculated with Dutch elm disease fungus showed only 5 per cent disease at the end of the season, reports A. E. Dimond, chief plant pathologist of the Connecticut Agricultural Experiment Station. Applied in the form of a spray and acting from inside the tree, the compound attacks the fungus at its source. Although the compound will need considerably more testing before it is put on the market, it is hoped that with the possible development of disease-resistant elms and the use of chemotherapy, Dutch elm disease may eventually be stamped out.

Photography in Science

Severo Antonelli, of Philadelphia, has opened a completely equipped photo color laboratory, which is prepared to accept exacting assignments in medical and research photography in colored or black-and-white still or motion pictures. It will also handle difficult problems in color photography involving strobe light or unusual laboratory techniques.

In New York, Heitz and Lightburn, distributors of the Swiss-built Alpa-Reflex and Alpa-Prisma-Reflex 35-mm cameras, also handle an annular lamp for macrophotography, which can be installed around any camera lens. It provides sufficient shadowless illumination for either color or black and white. A special device provides an object table for illuminating small objects from behind.

Battelle Memorial Institute is investigating such problems as what causes piston knock by means of an ultra high-speed motion-picture camera. Designed to take pictures at speeds up to 100,000 frames/second, the new camera resolves 30–40 lines/mm on 8-mm film, thus ensuring good detail. A single photographic series of 500 frames can be projected as a motion picture immediately after development of the film. The camera can be used to photograph luminous or nonluminous objects, for direct photography, shadowgraphs, or schlieren photography.

Wet-process autoradiography, developed by Henry J. Gomberg, of the University of Michigan, offers a new technique for photographing the individual cell in action. Introducing a tracer element into the blood stream of laboratory mice enables the scientist to arrest development at any stage. He can then study progressive photographs of, for instance, the formation and growth of cancer cells. This technique is one of the first results coming out of the Michigan Memorial Phoenix Project.

Corning Glass Works is producing a new kind of photo-sensitive glass to produce permanent three-dimensional photographs in a variety of colors. By means of "chemical machining," holes of a few thousandths of an inch, up to several thousands per square inch, and irregular lacelike designs can be made. The new product is expected to have important applications in electronics.

Shadowcaster, an apparatus that permits laboratory personnel to deposit a thin coating of tungsten, molybdenum, or other suitable material by evaporation on as many as six glass microscope slides at one loading, speeds and enhances specimen contrast. The entire unit is contained in a steel cabinet, $14'' \times 14'' \times 10''$. Power requirement is 700 w, 105–125 v, 60 c.

Safety First

Two investigators at the Philadelphia College of Pharmacy and Science have reported that a teaspoonful of 2 per cent iodine solution or tincture of iodine in a pint of water will sanitize eating and drinking utensils if they are immersed for 20 seconds. Solutions have no adverse effect upon utensils after repeated treatments. The research was carried out under a grant from the Chilean Iodine Education Bureau.

A hunting knife that can be bent at a right angle to the handle without breaking carries a lifetime guarantee against accidental breakage and a type of safety sheath giving maximum protection for the wearer. Blade is made of composite steel and iron.

Solid Cream

Expected to be on the market soon is a solidified cream that can be cut, wrapped, or handled, and yet will dissolve quickly in hot liquids. The taste of the gelatin component of the mixture cannot be detected in coffee or tea when present in a range of 1–40 per cent by weight. Variation is a powdered milk-gelatin mixture that can be redissolved in water. The inventor claims that it is also possible to use raw whole milk, pasteurized, homogenized, skim, evaporated, or condensed milk with gelatin in the same way.

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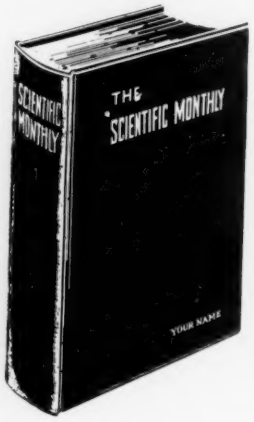

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THE
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JANUARY 1952

Symposium on the Role of Ecology in Water Pollution Control

The papers presented here are based on addresses given in the symposium sponsored by the Ecological Society of America at the Western Division meetings of the AAAS in Los Angeles last June. Concerning the authors, Dr. Ludwig and Mr. Paul are sanitary engineers, Dr. Mohr is a protozoologist, Dr. Newcombe and Dr. Phinney are botanists, and Mr. Oswald is a research engineer.

Role of Algae in Sewage Oxidation Ponds

HARVEY F. LUDWIG and WILLIAM J. OSWALD

Sanitary Engineering Laboratories, University of California, Berkeley

A SEWAGE oxidation pond is an economical biological device employed for the treatment of settled sewage, which is widely used in regions where the climate is sunny and dry. The sewage treated has undergone previous primary clarification, which removes the readily settleable solids, or about a third of the sewage organic material. The remaining soluble and nonsettleable suspended materials may be removed economically only by biological methods.

An oxidation pond is usually an artificially constructed shallow basin from 3 to 5 feet in depth, big enough to hold the flow for a period of 20–30 days. Through atmospheric re-aeration, oxygen is adsorbed into the pond, and aerobic bacteria convert much of the organic carbon contained in the sewage to carbon dioxide. The resulting environment is favorable for the growth of algae. Through photosynthesis these convert the CO_2 to algal cell material and simultaneously produce a surplus of oxygen beyond their own needs. The algae tend to predominate in the latter sections of the pond, where the water may become highly supersaturated with oxygen, and sometimes some of the pond effluent is recirculated back to the inlet. This transfers some of the excess oxygen to where it is most critically needed and also furnishes seed for promoting algal growth in the incoming sewage.

The precise role of the algae in proper pond functioning has not been completely evaluated. Such factors as the types and numbers of algae occurring, their nutritional requirements, the amounts of excess oxygen produced, the effects of antibiotics produced by them on bacteria and other microorganisms, etc., need to be studied, in order that pond designs may be most efficiently adapted to treatment requirements.

Laboratory Studies

The Sanitary Engineering Laboratories of the University of California are studying the growth characteristics of a single species of algae, *Euglena gracilis*, cultured in a sewage environment. *E. gracilis* frequently occurs in oxidation ponds and also

is commonly reported as an indicator of pollution in fresh-water streams and lakes. The Euglena are grown in the laboratory at constant temperature (25° C) in especially designed culture tubes (Fig. 1), which are subjected to continuous abundant light, and through which air is bubbled upwards to maintain a uniform suspension. Each day a fraction of the culture (the "yield") is removed from the tube, the amount depending upon the retention period desired, and an equal amount of settled sewage "food" is introduced into the tube. To begin a test for any given retention period, the sewage initially in the tube is heavily seeded with Euglena, after which the population of algae increases to an equilibrium, at which condition the test data are obtained.

The intense lighting on the tubes (averaging 1,200 ft-c throughout the tube) causes an acceleration of algae growth, as compared to actual pond conditions where lighting is not continuous and moreover does not penetrate throughout the pond depth. The cell population, or number of Euglena per ml of tube culture, is from five to ten times the total population of all types of algae observed in many pond effluent samples.

FIG. 1. Algae culture tubes.

The retention periods studied were varied from two to twenty days, with the result that the environment to which the algae were exposed varied progressively from very favorable (abundant nutrients) to unfavorable (shortage of one or more nutrients).

Cell Types and Properties

Microscopic examinations of the cells produced at varying retention periods show that *E. gracilis* can exist in many forms, corresponding to different environmental conditions. Figure 2 illustrates the changes in cell forms for retention periods varying from two days ($R = 2$) to twenty days ($R = 20$). At short retention periods, $R < 7$, the cells exist in an environment of abundant food, and reproduce and grow as rapidly as their rate of reproduction (about 24 hours) permits. The predominant forms are the mitotic (dividing) and the typical motile ("textbook") Euglena. At $R = 7$ the percentage and population of motile forms are at maximum, corresponding to a "most vigorous" condition, wherein the cell population is as great as possible for the nutrients available. As the retention period increases and the environment becomes progressively more unfavorable, the population of cells decreases, although their concentration, or weight per unit volume of culture, increases. The cells increase in size, reproduce more slowly, and accumulate fat. Some of them are forced into a "palmellar," or passive, state in which they have little motility, or into a "swarming" state, which is a highly motile form that may evolve from the palmellar state, and seems to be a "last-gasp" effort by the organism to find necessary nutrients or die.

Figure 2 shows also that as the organisms become "older" their color changes. In this case, where the bubbled air was not enriched with CO_2 (i.e., % CO_2 in air = 0.03), the average color varied from dark-green at $R = 2$ to yellow at $R = 20$. In other, earlier tests, employing air enriched with CO_2, the color varied from very dark-green at $R = 2$, to yellow at $R = 10$, to brown at $R = 20$. Comparison of the two sets of data indicates that at low retention periods the greater availability of CO_2 results in a greater rate of growth, but at high retention periods the organisms are overexposed to CO_2 and suffer injury.

Besides causing changes in the form and color of cells, changing the retention period affects the cell shape, size, and density. The younger motile cells are "slimmer" or more elongated. The individual cell size and weight decrease from $R = 2$ to

$R = 7$, as the environmental conditions remain favorable and more time for reproduction is allowed, but beyond $R = 7$ the cells become progressively larger. Thus at $R = 7$, the "most vigorous" condition, where the population of cells is at maximum, the cells are smallest and have accumulated little stored material. Beyond $R = 14$, when some nutrient becomes limiting, the individual cells become more dense, indicating that the very old cells store up products containing less water.

Oxygen Produced by Photosynthesis

Since the production of oxygen is related to synthesis of cellular material, the younger or more rapidly growing cells produce oxygen at a higher rate. In Figure 3 are shown curves illustrating (*a*) the rate of oxygen production by the algal cells in cultures at varying retention periods, (*b*) the rate of utilization of oxygen by algal cell respiration, and (*c*) the rate at which the same cells would exert a biochemical oxygen demand if dead. Two oxygen production curves are given, one representing photosynthesis 100 per cent of the time, and the other representing field conditions or photosynthesis during the daytime (12 hours per day).

The curves show that young cells, or those growing in a favorable environment, photosynthesize much more oxygen than they respire, whereas old cells respire more oxygen than produced; hence young but not old Euglena cells could be responsible for the supersaturation of oxygen found in many pond effluents. Examination of the types of algae occurring in actual ponds in California[1,2] has shown that *E. gracilis* is present in large numbers in many ponds, and when present occurs in the typical motile forms. This indicates that the environment obtaining under field conditions is favorable, and produces cell types similar to those produced in the laboratory culture tubes at low retention periods.

There is no direct relationship between the laboratory tube retention period and pond retention periods. The Euglena in ponds are not uniformly distributed but occur in zones of favorable environment. On the fringes of such zones some of the cells might be transformed into palmellar types and, losing motility, would tend to sink to the bottom.

A subject of great practical interest is what happens to young algal cells discharged from ponds into receiving streams. Whether the cells remain young, become old, or die will be determined by the new environment. If the stream at the place of discharge is polluted, the new environment should

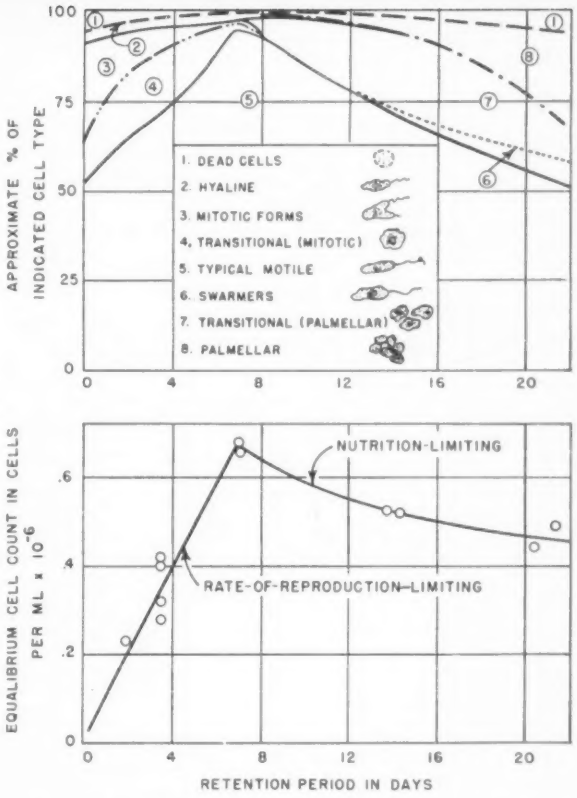


FIG. 2. Number and distribution by types of Euglena cells grown at varying retention periods.

be a favorable one, and the algae should be beneficial in producing a surplus of oxygen, which will assist in minimizing the oxygen sag. Farther down the stream, where after recovery the waters are clean and contain much dissolved oxygen, the environment becomes unfavorable; algal respiration may exceed algal oxygen production, resulting in a small oxygen demand. Thus the algae are beneficial where conditions are critical and oxygen is scarce, and will create an oxygen demand only when such demand has no significant deleterious effect. Similarly, death of the algae and an exertion of BOD by the dead cells should not occur to any significant extent except in very clean streams.

The discharged algae also constitute a living food, which may be of much value in sustaining fish and other wildlife.

Materials Balance

The amount of algal cell material produced at any given environmental condition is limited either by reproduction rates or by some nutrient. In oxidation ponds the limiting nutrient is probably CO_2. This is being produced continuously by bacterial action, so that the CO_2 concentration in the pond

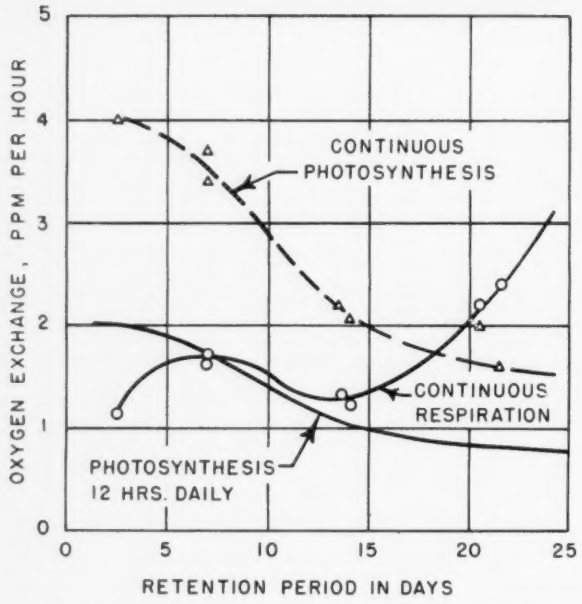


FIG. 3. Oxygen exchange capacities of algae cultures.

water is one of supersaturation with respect to the atmosphere.

The algae abstract much of this CO_2, and also abstract CO_2 from the alkalinity of the sewage, in accordance with the equation:

$$HCO_3^- \longrightarrow CO_2 + OH^-.$$

This reaction causes an increase in pH but no change in alkalinity. However, both laboratory and pond data show a reduction in alkalinity. This can only be due to the production by the algae of some acid substance. The laboratory data show that when *E. gracilis* is grown under conditions where CO_2 is not present in abundance the production of acid is increased and may become great enough to destroy all the alkalinity and depress the pH.

The laboratory data show also that the Euglena pick up and incorporate nitrogen, phosphorus, manganese, potassium, magnesium, and other minerals. At $R = 7$, the amounts of these constituents in percentage of the dry cell weight are as follows: Total ash, 10.0; N, 5.5; PO_4, 4.5; Ca, 1.2; Mg, 0.35; K, 0.35; and Mn, 0.001.

Yield of Algae

In recent years much study has been given to the feasibility of producing high-protein food by photosynthesis of algae. Cook,[3] studying yields of *Chlorella pyrenoidosa* grown under continuous illumination in an ideal synthetic nutrient prepared from commercial CO_2, fixed nitrogen, and other minerals, obtained yields as high as 0.48 g/l/day. Since settled sewage contains appreciable amounts of waste nitrogen (principally as ammonia and organic nitrogen), the bacterial-algal symbiosis may be considered a means for reclaiming the waste nitrogen in the form of algal cell material. The algae absorb the ammonia initially present in the sewage (20–40 ppm) and also the ammonia or nitrate formed by bacterial action on the organic nitrogen.

The maximum yield of *E. gracilis* occurs at a very low retention period (from 1.5 to 2 days), representing the minimum period that allows time for the cells, growing in an envrionment of abundant food, to reproduce sufficiently to build up a population. The maximum yield of *E. gracilis* obtainable from sewage is close to 0.26 g/l/day, if illumination is continuous and if the sewage is fortified with CO_2 to permit maximum extraction of nitrogen. Using a more rapidly reproducing species of algae, such as *Chlorella* or *Scenedesmus,* which are also at home and grow vigorously in sewage, the yield obtainable from sewage can probably be appreciably increased.

As compared with the use of synthetic media, the growth of algae with sewage offers several important advantages: (1) Fixed nitrogen is already present, or becomes available through bacterial action; (2) other minor or trace nutrients, such as phosphorus, are already present; and (3) much of the needed CO_2 is made available through bacterial action.

The algae cells may be readily separated from the culture medium by simple alum flocculation followed by settling. The cell material is a high protein food which, following sterilization, should be suitable for use as cattle feed. From "sewage to beefsteak" may be a real economic possibility.

References

1. LUDWIG, H. F., *et al. Univ. Calif. (Berkeley) Inst. Eng. Research Bull.* Ser. 44, (1), (Dec. 1950).
2. CALDWELL, D. H. *Sewage Works J.,* **18,** 433 (1946).
3. COOK, P. M. Large-Scale Culture of *Chlorella.* Presented at annual mtg. Phycol. Soc. Am., New York (Dec. 28, 1949).

Protozoa as Indicators of Pollution

JOHN L. MOHR

Department of Zoology, University of Southern California, Los Angeles

IN a discussion of protozoans as indicators of pollution it is appropriate (not to say convenient) to start with the relationship of these animals to waters contaminated with sewage. Sewage contamination occurs widely, it presents a moderately clear-cut ecological gradient, and it has been much studied.

It is well also to begin by drawing the distinction in indicator role between the coliform bacilli and the several protozoan species employed.

The sanitarian requires a reliable indicator of fecal contamination. Such an organism must be (*a*) invariably present in the mammalian alimentary tract; (*b*) not characteristic of any other locus; (*c*) survive a fairly long time, but not long enough to be viable far from the entrance of pollutant (thus not a spore-former); (*d*) highly dispersible; (*e*) easily cultured on good differential media. No protozoan, so far as we know, fulfills this series of desiderata.

In the first place, the enteric protozoans are much more variable in kind than their bacillary counterparts, and no one group of protists seems to be exclusively colon-inhabiting. The obligate enterozoans appear to be very fragile outside the alimentary tract, surviving in cysts from which they emerge when they reach another gut. Those protozoans found in solid wastes of mammals are not the enterozoans, but a group of polysaprobes, quite properly separated as the coprozoa or coprophiles.

The protozoans commonly encountered in water, then, are generally distinct from the alimentary tract forms. They may be derived in main from the soil fauna and from whatever infusions in the area have dried to cyst-laden dust. The nutritional-energy system from sewage, with evolving pH, Eh, DO, BOD, and temperature characteristics, will offer a spectrum of developmental possibilities for some scores of reasonably well-known protozoans.

It is possible to draw up clearly defined steps or levels of degradation of the sewage energy system with a number of protozoan species characteristic of each grade. For example, the organisms of the coprophilic grade—those living in excrement—may be segregated into polycoprophiles, mesocoprophiles, and oligocoprophiles, based on degree of dilution, etc., with requisite varying adaptation to the several levels of viscosity, pH, and available oxygen. Watson has provided a thoughtful, thorough review of this group.

The coprophiles correspond moderately well with the polysaprobes of Kolkwitz and the septic or saprobic level of Forbes and Richardson—representing a condition which requires no subtle indicators for detection, being the essence of the sedimentation tank or sewage treatment bed. The mesosaprobic, oligosaprobic, and katharobic zones all have their protozoan faunas, the mesosaprobic, which may be subdivided into alpha and beta levels, being the condition which the sanitarian and conservationist *inter alia* seek to spot promptly to take measures to achieve oligosaproby.

The distribution of protozoans in relation to pollutants unfortunately does not make a nicely defined pattern in reality; limitations become apparent quickly in practice. Ordinary plankton samples contain relatively few examples, as most of the critical indicator species are benthonic. The recent Conestoga survey, which employed two competent protozoologists, yielded protozoan indicators rather meagerly. Suspended samplers (as, for example, clusters of microscope slides) exposed for a period are capable of raising this yield. Irregularities of flow in lake, stream, or harbor result in warpings of yield as far from the predictions for the ideal pollution gradient system as the behavior of the actual gas is from that of the ideal gas of the gas laws. As Patrick has shown, samples on the two sides of a stream at a given level may contain indicators of quite different sorts. Perhaps more important, a number of good indicators of pollution, widely tolerant, may be found in many situations, but occur in large numbers only in a narrow band of the sewage-energy spectrum.

It should be stated explicitly that analysis requires some little competence. *Euglena*, *Paramecium*, and *Vorticella* are listed as typical polysaprobes—which they are. But only in some of their species. Lackey has studied the genus Euglena, indicating which species are useful indicators and with what qualifications. In the genus Paramecium, *P. putrinum* is a true polysaprobe, as its name well indicates; most of the species of Paramecium are mesosaprobes. *Vorticella microstoma* (with a narrow bell) is polysaprobic; *V. campanula* (with an open bell) is mesosaprobic. Many small flagellates

and ciliates are excellent indicators, but their usefulness depends on accurate identification, which requires careful examination and a modicum of background for the examiner.

We shall not speak of annual variation, which imposes additional limitation on the method.

On sober appraisal, then, one may say that protozoan counts from waters (particularly where full attention is given to the benthos) will characteristically provide indication of any sewage pollution. Further, experience of many workers has shown that the protozoans with other invertebrates will provide a better index of the character of inland waters than will chemical studies alone. However, although at least a presumptive case of pollution may be so established where such contamination exists, it is obviously better to depend on the total of evidence obtainable rather than upon the protozoan facies alone, even though that be highly useful.

Recent studies of the Southern California Marine Borer Council and concurrent assembling of data on Los Angeles–Long Beach harbor pollution by the Regional Water Pollution Control Board made possible some studies of protozoans under conditions of marine pollution. These, although barely launched, suggest that indicator protozoans will be strikingly parallel to the fresh-water indicators. Notably, the Vorticella from the one polysaprobic station sampled is a narrow-belled species strongly resembling *V. microstoma* of polysaprobic inland waters. *Ancyromonas* appears to be the marine counterpart of *Helkesimastix* of septic inland waters. The greater part of the harbor would appear to be in the mesosaprobic range (rarely oligotrophic), characterized by a number of the same genera of Protozoa as enriched (= polluted) "fresh" waters, Vorticella of the campanula type, *Epistylis, Vaginicola, Euplotes, Stylonychia,* and *Lacrymaria* among them.

In California a great bulk of pollution is from sources other than from domestic sewage—the most serious problem being probably the inland cannery wastes, for fish cannery wastes issuing directly or indirectly to the harbor resemble ordinary sewage in that quantities of organic material are broken down stepwise by action of organisms until they are inoffensive—on the way providing growth energies for various organisms.

Cannery wastes differ from domestic sewage on one hand in generally lacking pathogenic microorganisms and on the other, particularly for plant crops, in their extreme seasonal character—the whole seasonal discharge for a crop at a single cannery being a few weeks. The discharge is moreover at time of maximal heat while the streams are nearly at minimal flow. To my knowledge no study has been made of the effects on the river microbiota at Modesto, Stockton, or similar points, although they well warrant investigation. Although seasonal, too, the conditions with the fish canneries are less extreme, as the time is less concentrated and the body of water contaminated is much greater and of lower temperature.

The situations we have discussed thus far may be considered types of enrichment—provision of large amounts of complex food with attendant profound shifts in pH, oxidation-reduction potential, etc., still rather inadequately known. Effluvia of the food and beverage industries are likely to fall in this class. Lackey has studied distillery wastes in a small stream under peak summer conditions. He noted extreme rise in temperature, oxygen depletion with acceleration of BOD, a high bacterial flora, high phosphate, and evolution of hydrogen sulfide and methane. *Polytoma, Tetramitus, Enchelys, Metopus,* and similar "pollution" protozoans persisted until, in late summer heat, when the stream in question was composed almost entirely of distillery wastes, "even these tolerant forms tended to disappear."

Pollution as we see it in our lakes and streams and bays and even open coast is likely to have another aspect—the introduction of a wide range of toxicants separate from or imposed upon an enrichment. The effect of these toxic pollutants on the fauna is generally simply subtractive. For example, at one of our harbor stations phenols and chrome salts are known to mingle with oil refinery wastes and some domestic sewage. The protozoan fauna (as a matter of fact, the whole microbiome) is poor in species and individuals, and those present are rather typical polysaprobes. On evidence still rather slim, we suggest that some of the polysaprobes may have a measure of tolerance for assorted toxicants. In some cases toxicants may be present in such quantities as to kill off life completely in a drainage area, as in the celebrated case of the Rheidol River below the lead and zinc mines of West Wales, a stream derelict for many years, though now recovering. Where a toxicant lays waste a stream or harbor area biologically, the only "indicator" function of protozoans is in tests of toxicity of water samples for laboratory populations of such forms as *Paramecium caudatum* or vorticellids. Unfortunately, the well-devised studies of the return of the biota of the Rheidol have not included search for the protistan pioneers—species that should be of exceptional value as toxicant test animals.

For both fresh water and salt water, current

knowledge of protozoan ecology permits at least a qualitative indication of pollution by domestic sewage and probably by effluvia of most food processors. Such indications are more valuable if combined with concurrent study of the microflora—as clearly shown by Fjerdingstad's excellent study of the River Mølleaa. Usable quantitative measurements will require new methods of collection, culture, and analysis.

As to the possible usefulness of protozoans in the detection of a wide range of toxicants from industrial wastes, we have negligible data and so far other invertebrates have proved more popular as laboratory test animals for such agents.

Bibliography

FJERDINGSTAD, E. *Folia Limnol. Scand. (Copenhagen)*, (5), (1950).

LACKEY, J. B. *U. S. Pub. Health Service, Pub. Health Repts.*, **55**, (7), 268 (1940).

Ibid., **57**, (8), 253 (1942).

NEWTON, L. *Ann. Applied Biol.*, **31**, (1), 1 (1944).

PATRICK, R. *Proc. Acad. Nat. Sci. Phila.*, **101**, 227 (1949).

WATSON, J. M. *Biol. Revs. Cambridge Phil. Soc.*, **21**, (3), 121 (1946).

Aspects of Water Pollution Study in the California and Great Basin Area

CURTIS L. NEWCOMBE

Division of Water Pollution Control, U. S. Public Health Service, San Francisco

A SYMPOSIUM on the subject of water pollution may be introduced appropriately by brief reference to the National Water Pollution Control Program. The importance of biological research to the subject of water pollution control is established. Special interest centers in ecological investigations, since they are considered pertinent to the development of improved waste treatment techniques and to the general problem of pollution prevention and abatement. The following introductory remarks cover phases of the cooperative programs being developed in the California and Great Basin Area by state and federal agencies, and of the role of ecology in solving water pollution problems.

Progress in science and industry is accompanied by grave responsibilities to the people. One of these is to guard the quality of the nation's water resources. To an increasingly large extent, pollution of natural waters constitutes a direct threat to public health and to the successful economic exploitation of basic and essential natural resources. The U. S. Public Health Service has, since the turn of the century, been cognizant of this threat and water pollution control legislation has been debated frequently in the Congress. Finally, on June 30, 1948, the *Water Pollution Control Act* of 1948 (Public Law 845 of the 80th Congress) became effective. The act sets forth the declared policy of Congress to be: (1) to recognize, preserve and protect the primary responsibilities and rights of the states in controlling water pollution; (2) to support and aid technical research in order to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment; (3) to provide federal technical services to state and interstate agencies, and to industries; and (4) to provide financial aid to states, interstate agencies, and municipalities in the formulation and execution of stream pollution abatement programs.

Legislative authority of the states in the field of water pollution is vested in whole or in part in state health departments, in particular state water pollution control agencies, or in state fish and game departments. In the Great Basin states of Nevada and Utah, no comprehensive water pollution control law has yet been enacted, and the state health departments have major responsibility for water pollution control. In California,*

the 1949 Legislature established a State and nine regional water pollution control boards whose major responsibility is the abatement, prevention and control of pollution. Pollution is defined in the California statutes as an impairment of the quality of the waters of the state by sewage or industrial waste to a degree which does not create an actual hazard to the public health, but which does adversely and unreasonably affect such waters for various beneficial uses. The State Department of Public Health is given the responsibility for the abatement of contamination, which is defined as a hazard to the public health. In addition to dividing the responsibility for the prevention and control of contamination and pollution, the California legislature provides for decentralization of the water pollution control program by placing administration on a local or regional level, and also provides for

* Personal communication from Vinton W. Bacon, executive officer of the California State Water Pollution Control Board.

coordination of water pollution control activities of all state, federal and local agencies.

The Present Water Pollution Picture

Water demands for recreation, as well as for municipal, industrial, and agricultural consumption, are at an all-time high, a condition not surprising in the light of the industrial expansion and population growth throughout recent years. During World War II, few remedial measures could be undertaken. In the postwar period, however, construction of municipal treatment works accelerated rapidly. Thirty-nine plants were built in the United States in 1946, 93 in 1947, 176 in 1948, and 338 in 1949.[1] These 646 new plants are serving nearly 10 million people. Throughout these same years, pollution loads to the waters of the nation increased, leaving very little, if any, net gain; hence the need is great for more and larger plants to treat the ever-increasing volume of municipal waste.

Industry has shown a great awakening, both in its attitude and action toward handling and disposing of waste. One estimate indicates that industry will invest perhaps 5 billion dollars during the next decade in reducing water pollution.

Regarding the magnitude of the job to be done, a recent summary release[1, 2] of the Division of Water Pollution Control states

> that throughout the United States there are over 22,000 significant sources of pollution. These are divided nearly equally between 11,800 municipal sources and 10,400 industrial sources. The pollution load discharged to watercourses by the municipal sources comes from a total sewered population of nearly 92,000,000. Some degree of sewage treatment is provided at 6,700 of these municipal sources serving a population of 56,500,000. On the industrial side of the picture, 6,000 of the industries contributing to the pollution load produce organic wastes, and 2,900 produce inorganic wastes. Almost 700 of these plants produce wastes of both types. We still lack data on the kinds of waste produced by 2,200 industries. Twenty-six hundred of the industrial sources of pollution have treatment of one kind or another, and 3,700 are untreated. We still lack treatment data for 4,100 others.

For the country as a whole, about 10,000 new treatment plants, replacements of existing facilities, or enlargements or additions are now known to be needed to handle the combined municipal and industrial pollution load. Breaking that 10,000 figure down, over 6,500 municipal projects are called for, while the needs for over 1,600 municipal sources of pollution are still undetermined. Nearly 3,500 industries need new plants, replacements, enlargements or additions, but the needs of 5,500 industries have not yet been determined.

In the California and Great Basin Drainage Basins there are over 670 municipalities discharging wastes, with a population equivalent of over 9,000,000. There are also 580 known industries in this area that discharge wastes with a population equivalent of around 4,000,000.

In the California Drainage Basin, approximately 76 per cent of the sewered population is served by treatment facilities and for 67 per cent of this population facilities are adequate. Corresponding percentages for the Great Basin Drainage Basin are 31 and 17.

Of the 204 municipal sewage treatment construction projects required in the California Drainage Basin, 31 would serve communities with populations of 500 to 1,000; 72 would serve populations of 1,000 to 5,000; 28 would serve populations of 5,000 to 10,000; 34 would serve populations of 10,000 to 50,000; and 6 would serve populations of over 100,000.

Work in Progress

The Basin Office of the Public Health Service in San Francisco serves the California and the Great Basin Drainage Basins. Altogether there are fourteen[3] major drainage basins throughout the nation, each of which is divided into sub-basins for investigative purposes. Following the preparation of an over-all summary report[4, 5] for each major basin, there are being compiled, in cooperation with the state water pollution control agencies, rather detailed comprehensive reports on each of the sub-basins, setting forth the physical description of the area, the pollution loads contributed to water resources, the damages to water resources from pollution, the benefits resulting from pollution prevention and abatement, the pollution prevention methods in effect, and the pollution prevention measures required.

In a large region, such as the California and Great Basin Drainage Basins, totaling approximately 300,000 square miles in area with a population of 11.5 million people, there is the problem of how available resources for biological research may be best utilized. Consistent with the underlying principle of the *Water Pollution Control Act,* the Basin Office in San Francisco is undertaking to approach the biological problems jointly with state water pollution control agencies, with state and private universities and colleges, and with the biological laboratories of state fish and game departments and of other interested agencies whose basic programs are related to biological aspects of water pollution.

It is believed that the available resources of the Public Health Service will function most effectively by stimulating interest in, and offering assistance

to, established biological laboratories of the respective states where programs related to water pollution are already in progress. In this way advantage may be taken of existing facilities and the Service's somewhat limited funds may be correspondingly extended over a wider field. As examples of services provided by the Basin Office, limnological field equipment and modest laboratory facilities located at the University of California in Berkeley are made available for use in cooperative programs with the states.

In California, the State Water Pollution Control Board has initiated a permanent stream-sampling program whereby the major streams and lakes within the state are periodically sampled at more than 100 stations. Contracts have been awarded for more than 90 special investigations and studies on water pollution to be conducted during the 1951–52 fiscal year. By means of contracts with the California Institute of Technology, the University of California, and the University of Southern California, several major research projects are now under way. These include investigations on (1) water quality requirements for various beneficial water uses, (2) the travel of pollution with groundwater movement, (3) the pollution of underground waters by alkalies and salts leached from dumps, (4) waste water reclamation and utilization in relation to underground water pollution, and (5) a study of the algae of oxidation ponds used for treatment of industrial waste.

The Role of Ecology in Solving Water Pollution Problems

There are three principal sources of pollution of surface waters—namely, sewage discharged in its crude state and effluents from sewage treatment plants, industrial wastes, and natural silt. There are two main types of sewage treatment. Primary treatment removes from 40 to 60 per cent of the suspended solids by screening and sedimentation, and includes anaerobic digestion of the solids removed. Secondary treatment removes, by such means as trickling filters or the activated sludge process, the wastes that are in solution or in colloidal suspension. Both secondary treatment processes are largely dependent upon microorganisms. As a result of primary and secondary treatments, around 90 per cent of the organic matter originally present can be removed before the effluent is discharged. Trickling filters, commonly used in secondary treatment, consist of a bed of coarse stone, provided with underdrains over which the settled sewage is sprayed and allowed to trickle. Biological growths form on the stone of the bed, oxidize the organic materials, and produce an effluent with a remarkably low biochemical oxygen demand. High-rate filters may treat 20 million gallons per acre per day. This clearly represents a tremendous amount of work, a good example of applied ecology.

John N. Wilson[6] divides the microbiota of sewage treatment plants into three main categories: (1) the *binding* organisms, which comprise the fibrous gelatinous matrix of the biological film on the stone surfaces, are represented by the slime bacterium, *Zoogloea ramigera,* particular molds and fungi, and also filamentous algae; (2) the *free-living* organisms, including the higher bacteria, protozoans, and rotifers; and (3) the *grazing* organisms that include insect larvae, round worms, annelids, snails, and certain adult insects which feed directly on the biological film and sewage solids.

But not all waste treatment processes are confined to the complicated mechanical structures designed for primary and secondary treatments. In Arizona, Texas, and California, oxidation ponds are being increasingly used. These shallow lagoons, frequently spread out in series over many acres, perform an efficient purification job in a comparable way but do it quite cheaply. Bacteria, protozoans, algae, and fungi are the active biological elements.

Much progress in the study of the biology of waste treatment processes has been made since the late eighties when Dupré pointed out that the purification of sewage is brought about by organisms and that, with a sufficient number of organisms in the polluted water and plenty of air, the sewage could be dealt with in the easiest and most efficient manner. Interestingly, he stated that the organisms to which he referred might be sneered at, but that they were among the most powerful agents in the world.[3]

While it is now well established that microorganisms perform important tasks in the purification of wastes, the respective roles of the different kinds are not well understood. In fact, knowledge of the taxonomy of the biota is, itself, most inadequate. To permit maximum use of these highly important biological tools and to pave the way for needed improvements in certain treatment processes, ecological and physiological studies of the dominant plankton organisms in waste treatment processes are greatly needed. Specifically, information on their taxonomy and physiology may lead to guided manipulation of oxidation ponds as waste treatment units to obtain maximum biochemical efficiency, or to knowledge of advantageous inocu-

lation procedures, or to waste conditioning procedures that may provide a more efficient culture medium for the organisms concerned.

Wastes from manufacturing processes and from mines are of many kinds. Washings from coal, for example, contain comparatively inert suspended solids; those from agricultural processing plants contain dissolved and insoluble organic matter, those from the metal industries contain inorganic substances, some of which are toxic. The problems arising from the addition of these complex and diverse wastes to our water resources are most complex. It is preferable to think of the common dumping grounds for wastes as something more than just avenues of transport—streams, rivers and creeks—because they are important renewable natural resources. Often they influence more people and accomplish more good than the mines or the processing plants that spell their ruin.

At a time when trends toward urbanization and industrialization arouse concern for the nation's streams, rivers, bays, and harbors, when the recreational facilities of an expanding population are greatly overcrowded, silt is apt to be overlooked as it makes insidious inroads on the productivity of rivers and streams, lakes and reservoirs—nature's hubs around which revolve the recreational activities of millions of Americans. It is time to wake up to the facts about mistreated water.[7] Erosion silt from natural and human agencies has reached San Francisco Bay in prodigious quantities (Fig. 1). As in Chesapeake Bay and other comparable estuarine habitats, water productivity has declined in important ways.[8]

Profound changes in the character of a watercourse and in the distribution and numbers of its animals and plants may result from the suspended matter discharged with most domestic and industrial wastes. This matter may be inert material such as clay, or relatively inert particulate matter such as coal washings, or highly decomposable organic matter. If the sludge is inert, it may change for the worse the plant-animal community structure of the habitat; if it is organic substance, it may decompose anaerobically. In either case, pollution with its inevitable aftermath results. A. F. Bartsch[9] recognizes four merging stream-condition zones below an outfall bearing organic wastes—namely, zone of recent pollution, septic zone, zone of recovery, and zone of clear water. These zones are characterized by particular organisms. Each genus, and sometimes each species, have their own optimum for individual factors of the environment. There are differences, too, in the adaptive powers of each variety.

FIG. 1. More than 40 per cent of the San Francisco Bay area lies under less than five feet of water.

Much work is needed on the mechanical and biological changes in the aquatic habitat that are caused by wastes.[10] Poisoning by toxic metals lasts for varying periods, depending on the elements. Its effect on the natural stream biota depends upon the resistance of the particular species to the specific polluting substance. Furthermore, there is marked variability among individuals of a particular species. Some individuals are more resistant than others to the same dose of poison. Pentelow, working in England, was able to demonstrate that the effect of certain inorganic poisons appears to be simply a subtraction from the normal fauna as a consequence of differential toxicity. In other words, as the concentration of the metal pollutant became less, more species and more individuals were added. Although there were reductions in the number of species by poisoning, the resulting lack of competition failed to permit a compensating large increase in the number of individuals. In fact, the numbers were smaller than in the normal parts of the river.

Radioactive wastes comprise a new element in the waste disposal problem and in the ecology of aquatic environments.[8, 11] In the process by which plutonium is produced, a variety of radioactive substances is formed, many of which are at present

useless or too difficult to reclaim and must be satisfactorily disposed of. Since certain radioisotopes may emit radiation for thousands of years, since water dilution is one of the four principal methods of radioactive waste disposal (the other three are air dilution, storage, and burial at sea), since both microscopic and macroscopic aquatic organisms absorb and store radiation, and since isotopes are widely used, a broad and exacting research program is forced upon the student of aquatic life. Radioisotopes, added to natural waters, become available for incorporation into tissues, let us say, of a food fish, through direct absorption from the water, or indirectly through absorption from the planktonic food supply. All links in the food chain must be examined; nor should it be overlooked that microorganisms may serve an important function in radioactive waste disposal plants.[12] Water works engineers and biologists alike are faced with a new type of water pollution. The challenge is serious and urgent.

Organic waste produces very different faunal and floral changes. It exercises a positive, nutritive value whenever other depressive conditions permit. Large numbers of relatively few, nonnormal species result from discharges of these wastes. In many streams contaminated by organic wastes, tubificids, red Chironomids, and the so-called sewage fungus, *Sphaerotilus,* are the dominant Big Three organisms. Butcher[13] writes: "No matter what species make up the original river flora and fauna the above [three] are invariably dominant after pollution." Furthermore, in a downstream direction toward final recovery, not only are the same animals found in different streams, but they occur in the same succession. We recognize, then, in these facts the basis for a most stimulating and interesting field for ecological research, greatly in need of elaboration.

When chemical indices of pollution are not applicable, one may resort to biological criteria, or biometers. This complex phase of applied ecology is receiving especial experimental and field study by Clarence Tarzwell and his associates at the Environmental Health Center of the Public Health Service in Cincinnati.[14] There, special attention is being given to the value of particular stream forms as *indicator organisms.*

Three papers of this symposium are devoted largely to general subjects of wide scope and application and treat, at least in part, theoretical aspects of pollution problems. One paper concerns what might be called "the facts of life" in regard to what pollution has done and is still doing to the famous Pacific Coast streams. It should be kept in mind that these streams—their fish, their beauty, their enchantment—do not belong to us alone. They belong to all future generations as well. We are entitled simply to their use in our time. If we misuse them through unreasonable and inordinate pollution, then we have betrayed a responsibility as great as any, a trust as sacred as any.

References

1. U. S. Public Health Service. Water Pollution in the United States. Water Pollution Ser. No. 1, Public Health Ser. Pub., No. 64 (1951).
2. Schwob, C. E. The Nationwide Water Pollution Control Program under State and Federal Cooperation. Delivered before Natl. Wildlife Federation Conv., Milwaukee, Wis. (Mar. 3, 1951).
3. Wishart, J. M. The Work of the Chemists and Biologists in Relation to Sewage Purification and Disposal. Sectional Mtgs. Inst. Sanitary Eng., Denison House, Westminster, Eng. (1939).
4. U. S. Public Health Service. Summary Report on Water Pollution, California Drainage Basins. Water Pollution Ser. No. 5, Public Health Ser. Pub., No. 86 (1951).
5. ———. Summary Report on Water Pollution, Great Basin Drainage Basin. Water Pollution Ser. No. 4, Public Health Ser. Pub. No. 82 (1951).
6. Wilson, J. N. In F. R. Moulton (Ed.), *Limnological Aspects of Water Supply and Waste Disposal.* Washington, D. C.: Am. Assoc. Advancement Sci. (1949).
7. Newcombe, C. L. *Soil Conservation Mag.,* **16,** (12), (July 1951).
8. ———. *The Land,* **10,** (2), 177 (1951).
9. Bartsch, A. F. *Sewage Works J.,* **20,** (2), 292 (1948).
10. Doudoroff, P., and Katz, M. *Sewage and Ind. Wastes,* **22,** (11), 1432 (1950).
11. Higgins, E. *Trans. Am. Fisheries Soc.,* **79,** 217 (1949).
12. Eliasson, R., *et al. J. Am. Water Works Assoc.,* **43,** (8), 651 (1951).
13. Butcher, R. W. The Biological Detection of Pollution. Paper presented at Midland Branch, Inst. Sewage Purif., Birmingham, Eng. (Oct. 15, 1946).
14. Tarzwell, C. M., and Palmer, C. M. *J. Am. Water Works Assoc.,* **43,** (7), 568 (1951).

Water Pollution: A Factor Modifying Fish Populations in Pacific Coast Streams

ROBERT M. PAUL

Department of Fish and Game, State of California, San Francisco

INTEREST in the general relationship of fish populations to water pollution is not confined to academic discussion. In fact, the supreme interest in the subject is expressed by the angler who discovers a stream full of dead fish. We have found that other, slower acting forms of water pollution, though not so highly publicized, can change the complete ecology of an area surrounding a sewer outfall in a very inconspicuous but nonetheless disastrous manner. We find, for example, clam beds and spawning grounds which have been gradually destroyed or become populated by undesirable species. When this happens we realize that sporadic fish mortalities are relatively unimportant in the total picture of fisheries conservation, since natural reproduction and movement or in some cases stocking will quickly rehabilitate the degraded area. If, however, the physical environment has actually been degraded to a point where it is unsuitable, restoration becomes extremely difficult.

The redemption of chronically polluted areas imposes new functions on the conservation agencies: first, detailed biological studies; second, economic appraisal; and, finally, public education. In the past the California Department of Fish and Game's pollution control program, in common with that of similar agencies, has traditionally been based on law enforcement, and this type of control has been quite effective in some instances. The threat of prosecution and adverse publicity has, for example, reduced the number of accidental and intentional oil spills in our harbors. No preventive control or upgrading is possible, however. The law prohibits the discharge of deleterious substances, but abatement rests upon clear evidence, such as dead fish, that can be secured only after the violation has occurred. As a result, the volume of inadequately treated domestic and industrial waste has continued and increased to the point where even in the West some of our waters have been despoiled. Fortunately we do not yet have problems to compare with the industrial East, but even with our hundred-year "head start" restoring what we have already lost will require financial and personnel resources beyond what we have known in the past.

Water pollution problems in the West are greatly complicated by the seasonal and, to some extent, by the cyclical fluctuations in stream flow. In general all rainfall occurs during a few months of the year, and, as a result, the amount of water available for dilution of waste is extremely limited during the late summer and fall. The large deviation possible from the mean yearly rainfall also enters into our ecological picture, and the past seven years of drought conditions have had a tremendous effect on our fisheries resources, particularly in southern California.

In evaluating the effects of any one particular factor modifying fish populations, it is difficult to keep the other environmental forces in their proper perspective. In general, however, we believe that man-caused environmental change, including water pollution, constitutes the chief limiting factor in the development of the fresh-water fisheries resources of California, playing a more important role than the anglers' catch. We believe that ultimately the most important fisheries management tool will be environmental improvement—but not until we properly evaluate what has already taken place can we predict what will occur in the future. It is obvious that our present philosophy of pollution control must be changed to one of habitat or stream improvement and that the leader of this new concept must be the ecologist rather than the engineer.

In the West, even though climatological conditions may be radically different, the same general types of waste are encountered as elsewhere—namely, organic wastes causing oxygen depletion, wastes that are directly toxic, and nonorganic wastes which cause mechanical damage either to the fish directly or to their habitat. This arbitrary classification does not exclude the large number of wastes that can fall into more than one category. As an example, sawdust, one of our worst problems, has a theoretical ultimate oxygen demand of some 1,300,000 ppm. Sawdust also contains leachable toxic substances and can directly injure gill filaments through mechanical abrasion. In addition, sawdust settles to the bottom of the stream and is capable of burying spawning gravels and bottom organisms.

The most common and offensive type of water

pollution affecting aquatic life is the depletion of the dissolved oxygen in a stream, caused by the discharge of organic waste. Oxygen demand may be of an immediate chemical nature, such as that exerted by ferrous sulfate in the pickle liquor discharge from steel plants, but it is usually not fully exerted until the bacterial breakdown of carbonaceous material is completed, sometimes long after the concentration of dissolved oxygen falls below that necessary for the maintenance of fish life.

Lack of dissolved oxygen can affect fish populations in various ways, depending on the volume of waste and the physical condition of the receiving water. One typical situation occurs when sewage is discharged into a flowing stream. As the oxygen demand is exerted, the dissolved oxygen is depleted, and in many cases even though the rate of re-aeration prevents septicity the concentration of dissolved oxygen will drop to an unsatisfactory level over a portion of the stream. Although this relatively small zone is not of great significance to the resident fish population, it presents a complete barrier to any fish attempting to migrate upstream. This phenomenon occurs regularly on the Willamette River in Oregon[1] and is also well known in California. On the Sacramento River, for example, the discharge of untreated sewage and cannery waste from the city of Sacramento has lowered the dissolved oxygen to less than 4 ppm in the late summer, and the ever-increasing volume of sewage will shortly present a barricade to salmon and striped bass if treatment facilities are not constructed.

Oxygen depletion can also produce catastrophic fish mortalities if a large volume of waste is suddenly discharged into a stream. Under these conditions a "slug" of toxic water will move downstream and normal dilution is ineffective. This process results in widely publicized fish kills, although the permanent effects of this type of pollution do not appear to be serious, as the basic environment is seldom modified. If a steelhead or salmon run is wiped out in this fashion, the effects can be more serious and far-reaching, but it is very rare to have an entire year class decimated. In the case of warm-water species, population recovery is usually very rapid. As an example, in 1949 a levee at the City of Modesto Treatment Plant failed and a large volume of septic waste poured into the Tuolumne River of central California. This block of waste moved down the Tuolumne into the San Joaquin River, and eventually into the Delta region, where it was dissipated by tidal action and re-aeration. The fish populations in these rivers were wiped out as this mass of waste moved downstream, and hundreds of tons of dead fish were observed. More than 40 tons, consisting mostly of carp, were removed from one irrigation pump intake alone. As soon as this block passed downstream, conditions returned to normal, fish from adjoining waterways immediately moved into the area, and very little difference in angling success was noted even a few days after the catastrophe had occurred.

In cases where dilution and transporting capacity are limited, such as the discharge of waste into a tidal estuary, complete oxygen depletion usually results and conditions are unsatisfactory for any type of fish life. This condition occurs annually in California at Stockton and San Jose with the advent of the canning season, and fish populations generally leave the affected area before extensive mortality occurs. In most of these instances, however, the continued discharge over the years adversely affects the habitat, and, even during the periods of the year when water conditions are satisfactory, fish life is not abundant in the area, probably because the bottom is covered by sludge deposits made up of settleable sewage solids. The cure in these instances is the construction of sewage treatment facilities to prevent further degradation. It is felt that by stopping the influx of raw sewage the sludge deposits will gradually oxidize and disappear, and a normal fauna will be re-established, although in cases where the sludge beds are extensive, the process may require a considerable time.

The effects of waste discharges containing inert or nonorganic material are somewhat similar to the discharge of sewage containing a high proportion of settleable solids, although the effects are not so evident, for the most offensive conditions, such as odors and paint damage from hydrogen sulfide, are not present. The long-range environmental effects of this type of pollution are easy to visualize and have been encountered extensively in the past. In general these effects are cumulative and the principal result is the smothering of bottom organisms, particularly in bays and estuaries.

Suspended particles can also have a directly deleterious effect on fish life. For example, specific experiments have shown a reduced hatch of salmon eggs in the presence of mining silt,[2] and sharp angular particles such as those discharged from a quartz stamping mill can produce a direct injury through mechanical abrasion. The blanketing of bottom organisms, however, and the reduction of light penetration by suspended particles remain the most serious aspects of this type of pollution. The cure in many of these cases is not evident, but some control can be exercised over mining opera-

tions, particularly at the local or county level. The question of silt is involved with the far greater problem of soil and range management, and eventual control will depend upon the extension of soil conservation activities.

The third large category of stream pollution is that caused by the discharge of materials directly toxic to fish or aquatic life. These instances have been relatively rare in the past, at least in California, and have not had serious environmental effects, since they have been of an intermittent rather than of a continuing nature. Our chronic cases of heavy metal pollution, for example, are confined to leachings from abandoned slag piles and dumps in the upper Sacramento River drainage. Although the resident population is apparently acclimated, the concentration of copper in the streams of this area is sufficiently high to prevent the introduction of hatchery-raised fish. An exceptional case occurred on the Mokelumne River of the Central Valley, where shaft drainage from mining operations kept both the copper and zinc concentrations above the toxic level from 1943 to 1945. As a result, all forms of aquatic life virtually vanished, and it was not until 1949 that fish life again was re-established in the affected portion of the stream. During the same period the salmon run in this river declined from 40,000 to 100 fish per year, probably as a result of the combined effects of pollution and an inadequate fishway.

Within the past two years fisheries workers have seen a number of fish mortalities caused by a new type of toxic material. This pollution has been due to the increase in the use of so-called economic poisons and insecticides, beginning just after the last war with the introduction of DDT. At the same time the toxicity of these poisons to fish life has constantly increased, until the toxic level with the chlorinated hydrocarbons such as toxaphene is about 1 part in 25,000,000. Airplane spraying of toxaphene for mosquito control in California and for cotton weevil control in the Southern states has resulted in extremely serious losses of fish life over wide areas. Although airplane spraying is the most difficult to control, the increasing use of rotenone as a cattle spray has also presented problems. Our experience shows that a considerable amount of this spray is wasted, with resulting fish mortalities, particularly in our coastal salmon and steelhead streams. In both of these instances and in numerous others, a vigorous public education campaign will be needed to demonstrate to users of the sprays that the material is extremely toxic to fish life and must be excluded from our waters.

It is obvious that we cannot expect even to hold our present position unless a considerable amount of planning is given to the effects of the ever-increasing numbers and types of waste discharges. This is particularly true with regard to the growing possibility of radioactive pollution. The use of radioisotopes is constantly increasing, and even with minute discharges the cumulative effects of long-lived isotopes may be serious, as biological concentration of radioactive wastes is very effective and is, in fact, being used as a means of treating wastes containing highly toxic although "man-made" materials such as plutonium.[3]

There is one other hazard to our aquatic resources that is even more urgent than the problem of radioactive waste disposal and this is the increasing use of detergents and other surface-active agents. The use of detergents for household and industrial purposes continues to expand, and the trend shows no indication of leveling off. Although their use became general ten years ago, we are just now beginning to study the effects of these chemicals on aquatic life. Our own studies now under way indicate that the toxic level for common household detergents may be as low as 10–20 ppm. More important, there is considerable indication that these compounds do not decompose readily and that there is very little removal effected in ordinary sewage treatment facilities. Similar findings have recently been reported from Europe, and workers there[4] have shown that a concentration of 5.0 ppm of various anionic and nonionic surface-active agents had a lethal effect after 10–100 hours, depending on the species of fish and the type of detergent. The anionic detergents were quickly decomposed by bacterial action, but the nonionic types deteriorated much more slowly, with the active concentration dropping from 25 to 15 ppm in 14 days. At the present time it is believed that sufficient dilution capacity is available for all sewage discharges in California, but it is apparent that the increased use of detergents may produce serious effects on rivers receiving waste from a number of cities. It is not too cheering to note that, as far as the aquatic environment is concerned, the worst effects of both detergents and radioactivity may be combined in the event of large-scale radiological decontamination after an atomic attack.

By now it should be apparent that it is extremely difficult to separate the problem of stream pollution from the over-all picture of the conservation of our natural resources. To return to the example of the lumbering industry, for the present the pollution control program on our salmon and steelhead streams must be directed at preventing the discharge of debris and the sudden draining of mill-

ponds during periods of low flows. This activity, however, is useless in the long run if the operation of the same mill is responsible for a downstream log jam that is a complete barrier to anadromous fish. At the same time, the only possible final solution and the only way of ensuring the future of our fisheries and forests is the general adoption of sound forest management practices, but unfortunately there is no agency or group in California with the backing or perspective to successfully underwrite such a program at present.

In conclusion, there is no question that in order to perpetuate our fisheries resources a new philosophy of habitat improvement must replace our current idea of pollution control and that ecologists must enter the field of fisheries conservation in sufficient numbers to complete the inventory of our current resources before restoration is out of the question, and to anticipate future deleterious changes before they occur. There is some solace in the fact that our problem is not new—in fact, a good summation recently quoted by Gordon Fair[5] was made by the poet Coleridge around 1800 during a trip to Cologne:

> The river Rhine, it is well known,
> Doth wash your city of Cologne;
> But tell me nymphs! What power divine
> Shall henceforth wash the river Rhine?

We can only hope that the "power divine" continues to operate for another 150 years for the protection of our aquatic resources.

References

1. Fish, F. F., and Wagner, R. A. *U. S. Fish and Wildlife Serv. Spec. Sci. Rept.: Fisheries No. 41* (September 1950).
2. Shaw, P. A., and Maga, J. A. *Calif. Fish and Game*, **9**, 1 (1943).
3. Newell, J. F. *Exploratory Studies on the Removal of Plutonium from Liquid Wastes by Activated Sludge.* AEC Doc. No. AECD–2712 (1949).
4. Degens, I. P. N., Jr., *et al. J. and Proc. Inst. Sewage Purif.* (England), Part **I**, **63** (1950).
5. Fair, G. M. *Sewage and Indust. Wastes*, **23**, (4), (April 1951).

Some Relationships of Phytoplankton to Pollution

HARRY K. PHINNEY

Department of Botany, Oregon State College, Corvallis

THE recent recognition of the occurrence of variations in patterns of metabolism among members of algal phyla has opened many new avenues of research concerning the segment of the planktonic protista recognized as possessing algal affinities. Historically, effort has been expended in three main channels with relation to the phytoplankton: the taxonomic approach that has occupied the attention of the majority of phytoplanktonologists; the limnological or ecological approach of Wesenberg-Lund, Birge and Juday, and others; and the pure culture approach, whose main exponent until recently has been Pringsheim. Until the past decade or so these various directions in research have been most often pursued as an end unto themselves. The contributions derived from them will, however, provide indications of the critical points needing further investigation. Certainly any phytoplanktonologist can suggest from the store of known forms those whose peculiarities are such as to require detailed investigation. The limnologists have already outlined the majority of the factors that need critical restudy, and the culturists have provided a tool that at present promises much in the elucidation of our problems.

Among the plankton algae commonly occurring in waters subject to pollution, taxonomists have repeatedly indicated that in the Chlorophyta the Volvocalean and Zygnematalean forms demand attention. In the Chrysophyta the entire aggregation of motile unicellular and colonial species should be investigated, but initially such forms as *Synura, Botryococcus*, and *Mallomonas*, and the planktonic diatoms such as *Asterionella, Cyclotella, Fragellaria*, and *Synedra* strive for primacy in our attention. Finally, the planktonic members of the Cyanophyta are notorious above all others by reason of their nuisance value. Here *Diplocystis* (*Microcystis*), *Aphanizomenon, Anabaena, Lyngbya*, and *Oscillatoria* vie for precedence.

Many of these forms are receiving attention both here and abroad at the present time. In this country Bold, Lewin, Smith, and others appear primarily interested in the Chlorophyta. Hutner, Prova-

soli, and Palmer are opening up investigations with the Chrysophyta. Palmer is also planning an attack on certain features of the Cyanophyta, as are Gerloff, Skoog, and others at Wisconsin. The various groups of course direct their approaches to these problems in different ways. Some are working on mineral nutrition, some are making rate-of-growth and reproduction studies, others are interested in the biochemistry of the organisms that are not strictly autotrophic, and still others are mainly interested in investigating the chemical nature of the odoriferous products of the metabolism that render a number of organisms noxious.

The relationships of the phytoplankton to the physical, chemical, and biotic factors in the aquatic environment are exceedingly complex. Figure 1 shows the major features of this relationship as it involves the fixed carbon cycle and those mineral nutrients that are already combined in organic compounds. The multiplicity of connections exhibited here does not exhaust even the obvious possibilities, but they are intended to suggest some points for discussion. The dotted lines indicate connections upon which our present knowledge casts more than moderate doubt.

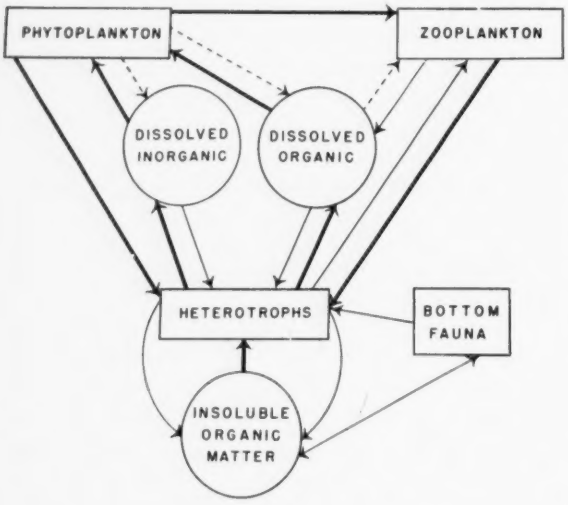


FIGURE 1.

Relationship of Phytoplankton to Zooplankton

The importance of the photosynthetic acivity of the phytoplankton in providing a fixed carbon source suitable for the development of a faunal population has been responsible for the expression of much interest in the amount and eventual utilization of the organic material so produced. The fact that this material is usually considered to be carbohydrates may have obscured the need for information concerning the fate of a number of organic materials produced in the metabolism of the autotrophic phytoplankton. The studies of Heilbron and co-workers[1–3] and Mazur and Clark[4] demonstrated the presence in algal cells of complex organic materials other than carbohydrates that may be of importance in zooplankton nutrition. We need to establish the importance of the chemical nature of all these materials in a phytoplankter in determining its selection as a food organism. Observations unsubstantiated by detailed study seem to me to indicate that the Chlorophyta are especially prone to serve as a carbon source for holozoic and saprophytic forms. Perhaps the relative availability of the carbon of the sugars and starch as compared with the carbon of other polysaccharides, fats, and oils may operate as a determining factor. Whether any of the phytoplankton forms produce known or unknown vitamins upon which members of the zooplankton population are reliant is another facet to be considered. The work of Hutner[5, 6] on the Euglenophyta and of Provasoli and Hutner[7] on the Chrysophyta is particularly interesting and important in indicating some of the tools and approaches that may be used in the study of vitamin production and utilization. It is probably unnecessary to point out that the chemistry of the metabolic products of algal organisms is poorly understood. Interest should not be restricted to obvious stored food materials or to aromatic substances but should include wall materials, sheath substances, and those organic and inorganic substances that are given off by the living cells. Since the metabolic pattern has a phylogenetic basis, as has been established by Heilbron,[2] Strain,[8] and other workers, this particular phase of investigation will not necessarily prove as unending as seemingly are the number of algal species.

Relationship of Phytoplankton to Dissolved Substances

Voluminous data on nutrient minerals have been assembled by limnologists and are of interest insofar as unspoiled natural waters are concerned. Data derived from such situations are of limited value in pollution work when it is recognized that in unspoiled habitats the concentration of dissolved inorganics probably seldom reaches a level that allows maximum growth of phytoplankton (Gerloff *et al.*[9]). However, such concentrations must occasionally occur under conditions of pollution, and, if for no other reason, it is therefore important that optimum concentration of the various nutrient minerals be determined for the most important phytoplankton constituents.

Such information as is at hand does not allow

determination of the possible interrelationships of the mineral substances in nutrition. The roles of nitrogen and phosphorus, probably the two most intensively studied elements, cannot be explained as yet with any confidence. Wesenberg-Lund[10] and Pearsall[11–13] have contributed much to our knowledge of the role of the major nutrient elements, and were primarily responsible for the importance attached to the nitrate nitrogen/phosphate phosphorus ratio in determining the distribution of species and the occurrence of blooms. Widely accepted though the ratio concept may be, it must face serious challenge from observations and experimental data of other workers. For example, Einsele[14] believed there was a definite connection between the metabolism of phosphorus and that of iron. Lackey[15] proposed the possible limiting effect of phosphorus alone, whereas Gerloff *et al.*[9] championed nitrogen as the important factor in bloom production. The work of Rodhe[16] indicated that, at least in *Asterionella,* phosphorus metabolism is complicated by other controlling factors, and Hutchinson[17] believed that in at least one situation he studied there was no evidence that the appearance of *Asterionella* depended upon the inorganic nutrient level. Admitting a lack of uniformity in experimental material in these various studies, which makes evaluation of the results difficult, it would seem that the relationship will eventually prove to be more complex than has been generally accepted. This last observation indicates that pure culture work provides us with only indications of the stresses resulting from the operation of physical and chemical factors of the environment. In pure cultures interspecific antagonism and competition are nonexistent and, furthermore, the diminishing concentrations of some or all nutrients contrast unfavorably with the constant replenishment found in most natural situations.

As suggested by Hutchinson[17] and Provasoli and Hutner,[7] the increasingly evident importance of minor elements, growth-factor materials, and preformed nutritional substances in the successful growth and multiplication of microorganisms should direct some research effort toward establishing the relationship of the phytoplankton to the dissolved organic, as well as the dissolved inorganic, substances in the environment. As indicated in Figure 1, these materials have various sources. Digestion of the organic detritus by the heterotrophic element of the flora is one; death and defecation of bottom fauna and zooplankton another; the third source, in the phytoplankton, may arise by secretion from living cells or by release of substances from the cells following death.

The most obvious primary connection of the phytoplankton to dissolved organic material is utilization by the plants of preformed carbon sources. Jacobsen,[18] Artari,[19] Pringsheim,[20] Bristol-Roach,[21] Skinner and Gardner,[22] and Collander[23] have shown that a great many algal organisms of supposed autotrophic nutrition can make use of soluble carbohydrates, fat soluble organic compounds, and sodium and potassium salts of various organic acids. The possibility that autotrophic organisms might make use of nitrogenous organic compounds has been taken into account very little in the past. Algeus,[24] however, has presented well-substantiated evidence that some fourteen species, belonging to seven genera, of Chlorophyta are able to deaminate aspartic acid; other substances such as glycine, succinamide, and asparagine are likewise deaminated with greater or less success. Considerable variation from species to species in success in deamination is apparently due to an inhibiting effect of the decomposition products formed during deamination. It would be reasonable to suppose that some of the phytoplankton species that are dominant in a milieu of extremely high organic content prosper by reason of their success in utilizing preformed substrates. It will be necessary to discover which species these are and the mechanisms by which their normal autotrophic processes are short-circuited.

Since the loss of the autotrophic habit is generally considered to be accomplished in a stepwise fashion, resulting in increasing synthetic disability, there are other forms among the chlorophyll-bearing organisms common in polluted habitats that should be investigated. These are forms that have lost one or more steps in the synthetic chain of metabolism and utilize preformed organic materials in an obligate rather than a facultative fashion as previously described. The nutrition of these organisms may best be indicated by the term "mixotrophy." A knowledge of their metabolism would be useful in an understanding of the interrelationships of the biota of polluted waters, and in addition the final elucidation of the entire photosynthetic process may well depend upon evidence derived from this type of aberrancy in nutrition.

Indirect Relationship of Zooplankton and Phytoplankton through Dissolved Organic Materials

Here, again, opinions are at variance. Putter[25] ascribed the maintenance of all animal groups up through the fish to the presence in the water of dissolved materials that escape from living algal

cells. Krogh and co-workers[26] have attempted to prove the absence of this relationship by showing that an algal culture loses less than 10 per cent of the organic increment from the cells to the surrounding medium during any given growth period, and furthermore they attribute most of this loss to death of cells. Kaloc,[27] on the other hand, has shown that cultures of *Vaucheria* in liquid produce precipitates of calcium oxalate, and that on agar *Vaucheria* spp. secrete a guttation fluid containing potassium, calcium, magnesium, carbonates, and phosphates as well as sugar. We know that certain algal organisms release specific sex hormone substances into the medium at the time of reproduction. The works of Moewus[28] have tended to clarify the chemical nature and physiological activity of these substances as far as the Volvocales are concerned. We know that many chemotactic materials must be released into the water during sexual reproduction of the different algal species, as the species are extremely selective and specific in their reactions to these substances. The question of their chemical nature remains to be answered, as does the question of the possibility of the utilization of these and similarly secreted substances by the animal members of the population.

Two topics discussed in the original form of this report are omitted here by reason of space limitation. One was concerned with the relationships between plankters and heterotrophs in view of vitamin production by the latter group (Robbins[29]), and the other was a discussion of the phytoplankton as a producer of autochthonous detritus (insoluble organic material) and thereby of sapropelic sediments (Phinney[30]). In addition it was pointed out that there is a great necessity for continuation of classical taxonomic and limnologic studies to suggest entities whose tolerance of the physical, chemical, and biotic stresses is such as to render them likely indicator organisms.

References

1. Heilbron, I. M., Parry, E. G., and Phipers, R. F. *Biochem. J.*, **29**, 1376 (1935).
2. Heilbron, I. M. *Nature*, **149**, 398 (1942).
3. Carter, P. W., Heilbron, I. M., and Lythgoe, B. *Proc. Roy. Soc. (London)*, B, **128**, 82 (1939).
4. Mazur, A., and Clark, H. T. *J. Biol. Chem.*, 143, 39 (1942).
5. Hutner, S. H. *Arch. Protistenk.*, **88**, 93 (1936–37).
6. ———. *Trans. N. Y. Acad. Sci.*, **20**, 136 (1948).
7. Provasoli, L., and Hutner, S. H. *Science*, **112**, 425 (1950).
8. Strain, H. H. In G. M. Smith (Ed.), *Manual of Phycology*. Waltham, Mass.: Chronica Botanica (1951).
9. Gerloff, G. C., Fitzgerald, G. P., and Skoog, F. In J. Brunel (Ed.), *The Culturing of Algae*. Yellow Springs, Ohio: C. F. Kettering Foundation (1950).
10. Wesenberg-Lund, C. In Murray and Pullar (Eds.), *Bathymetrical Survey of the Scottish Freshwater Lochs*, **1**, 374 (1910).
11. Pearsall, W. H. *Proc. Roy. Soc. (London)*, B, **92**, 259 (1921).
12. ———. *J. Ecol.*, **9**, 241 (1922).
13. *Ibid.*, **20**, 241 (1932).
14. Einsele, W. *Arch. Hydrobiol.*, **29**, 664 (1936); *ibid.*, **33**, 361 (1938).
15. Lackey, J. B. In F. R. Moulton (Ed.), *Limnological Aspects of Water Supply and Waste Disposal*. Washington, D. C.: Am. Assoc. Advancement Sci. (1949).
16. Rodhe, W. *Symbolae Botan. Upsalienses*, **10**, (1), 1 (1948).
17. Hutchinson, G. E. *Ecology*, **25**, 3 (1944).
18. Jacobsen, H. C. *Zeitschr. Botan.*, **2**, 145 (1910).
19. Artari, A. *Jahrb. wiss. Botan.*, **52**, 410 (1913).
20. Pringsheim, E. G. *Beitr. allgem. Botan.*, **2**, 88 (1921); *Naturwissenschaften*, **23**, 110 (1935); *Pure Culture of Algae*. Cambridge, Eng.: University Press (1949).
21. Bristol-Roach, M. B. *Ann. Botany*, **41**, 509 (1927); *ibid.*, **42**, 317 (1928).
22. Skinner, C. E., and Gardner, C. E. *J. Bact.*, **19**, 161 (1930).
23. Collander, R. *Physiol. Plant.*, **3**, 45 (1950).
24. Algeus, S. *Physiol. Plant.*, **1**, 236 (1948); *ibid.*, 2, (3), 266 (1949); *ibid.*, 3, (4), 370 (1950).
25. Putter, A. *Die Ernahrung der Wassertiere*. Jena: Fischer (1909).
26. Krogh, A., Lange, E., and Smith, W. *Biochem. J.*, **24**, (2), 1666 (1930).
27. Kaloc, J. *Spisy Prirod. Fac. Univ. Karlov.*, **158**, 1 (1938).
28. Moewus, F. *Arch. Protistenk.*, **80**, 469 (1933); *Biol. Biol. Zentr.*, **60**, 143 (1940).
29. Robbins, W. J., Hervey, A., and Stebbins, M. E. *Bull. Torrey Botan. Club*, **77**, 423 (1950).
30. Phinney, H. *Am. Midland Naturalist*, **35**, 453 (1946).

The Current Long-Range Forecasting Program of the U. S. Weather Bureau

JEROME NAMIAS and WALTER G. LEIGHT

Jerome Namias, one of the world's leading authorities on extended forecasting, received his M.S. from MIT and served there as a research associate from 1936 to 1940, the period during which extended forecasting research, described in this paper, was begun. Since 1941 he has been chief of the U. S. Weather Bureau's Extended Forecast Section in Washington, D. C. He is the author of many papers on meteorological subjects. Walter G. Leight received his B.S. from CCNY in 1942 and took graduate training in meteorology at MIT as an Air Force Cadet in 1943. He has been engaged in extended forecast operations and research since 1944 and has been on the staff of the U. S. Weather Bureau's Extended Forecast Section since 1946.

THE government's interest in the field of long-range forecasting was stimulated during the dust-bowl days. In 1935, in cooperation with the Bureau of Agricultural Economics and the Massachusetts Institute of Technology, the Weather Bureau made a systematic study of all available literature on alleged systems of long-range forecasting. The results of these studies indicated that the only one showing skill above chance was the German long-range forecasting system under the direction of Franz Baur. Although many other methods investigated attempted to explain the forecast weather chiefly on the basis of only one variable—such as sunspots or the moon—Baur attempted to consider many factors. Some of these were based upon soundings of the upper air in layers 10–30,000 feet above the earth's surface.

With ideas gleaned from these studies and from experience with upper air data as observed over the United States, a joint Weather Bureau–MIT project began to develop a practical method of long-range forecasting. The attack was one in which theoretical studies and empirical results were developed in close harmony. In 1941 the project was moved to Washington, D. C., as an operational and research unit of the Weather Bureau, the purpose of which was to issue forecasts for six days in advance. This unit has been functioning since that time, preparing five-day forecasts twice each week. During World War II long-range forecasts for many areas, foreign and domestic, were supplied to the armed services. In addition, a program of experimental monthly forecasts was begun in 1942. Today approximately 3,000 subscribers receive monthly predictions twice each month, and a briefly worded summary reaches millions through press and radio.

The very foundation of long-range forecasting is the realization of the global nature of weather patterns, that weather conditions in a given area may be determined by far-off events. This approach, through what is called the general circulation of the atmosphere, has shown greater skill over chance than purely local methods. It has been demonstrated that large-scale circulations must exist in the atmosphere as exchange mechanisms for such quantities as heat and angular momentum; hence the first step in the preparation of a long-range forecast is to determine the state of the atmosphere over the entire Northern Hemisphere and to heights up to 30,000 feet above sea level. This is accomplished by international exchange of weather reports.

Observations of pressure, temperature, and moisture are obtained at various levels in the atmosphere by means of small radio transmitting instruments called radiosondes, which are carried aloft by balloons. Wind measurements are made by following balloons with the aid of theodolites and radar. These observations are utilized in many ways,

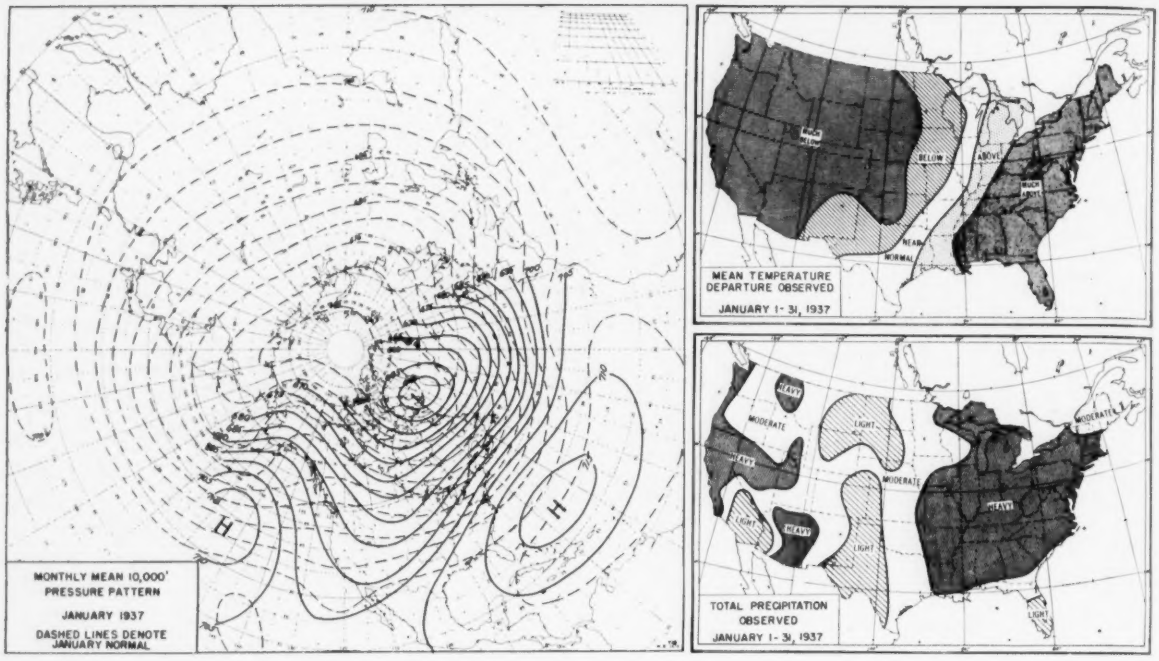
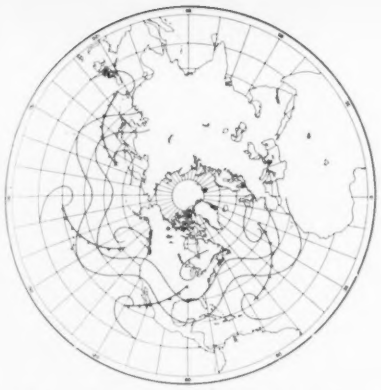


FIG. 1. Chart on left depicts the monthly mean 10,000-foot pressure pattern (solid lines labeled in millibars) for January 1937 with January normal indicated by dashed lines (also labeled in millibars). Observed surface temperature anomalies and total precipitation amounts for January 1937 are shown on right.

one of the commonest being the charting of the pressure distribution at a fixed level (say, 10,000 feet) or, equivalently, the determination of the height contours of a given pressure surface (such as 700 millibars) in the free air. These methods of charting make it possible to obtain a picture of the flow aloft, since there is a well-defined relationship between the isobars (i.e., lines of equal pressure) and the wind. The relationship (known as Buys-Ballot's law) is such that in the Northern Hemisphere the winds aloft blow parallel to the isobars with lower pressure on the left as one faces downwind; the velocity of the air current depends largely on the spacing between isobars (the pressure gradient).

If daily maps are averaged at some level for a given month over many years a normal map results. The normal distribution of pressure at 10,000 feet for the month of January, for example, is shown by the dashed lines of Figure 1. From the relationship between pressure gradient and wind it is seen that the flow of air in temperate latitudes of the Northern Hemisphere is in general from west to east. This westerly drift is not *exactly* west-to-east, for there appear to be waves making the flow curve in a roughly sinusoidal fashion. These disturbances in the westerly currents aloft are established in part by the distribution of continents and oceans over the earth's surface.

In Figure 2, a schematic model of the westerly drift over the Northern Hemisphere, a series of these waves in the westerlies is indicated. A perturbation off the eastern coast of Asia in the form of a trough probably results from the extremely cold air masses from Siberia being forced over the warm Japanese Current in winter. When the initial westerly current is disturbed a series of waves is created downstream. In Figure 2, for example, troughs appear in the eastern Pacific, over eastern North America, and near the Azores. These waves have an important effect on the weather as cold air masses are transported southward by the northwest winds behind the troughs and warm air masses are brought northward ahead of them. As a result of the convergence of these dissimilar air masses, strong discontinuities, or fronts, are established, and these result in most of the storms of temperate latitudes. An idea of the importance of these troughs may be seen in Figure 1, in which the mean pressure pattern at 10,000 feet for the month of January 1937 is shown by the heavy lines and the dashed lines, as stated above, indicate the normal January pattern. The corresponding precipitation amounts and departures from normal of temperature over the United States are shown on the right side of the figure. Severe floods in the Ohio Valley, as well as severe cold and freezes in the West, involving the California area, were ex-



$$C = U - \frac{\beta L^2}{4\pi^2}$$

$$L_s = 2\pi\sqrt{\frac{U}{\beta}}$$

FIG. 2. Schematic model of long waves in the westerlies. Equations on right express trough speed, c, and stationary wave length, L_s, in terms of the zonal wind, U, the variation of the Coriolis parameter, β, and L, the wave length.

perienced during this month. The Ohio Valley floods occurred to the east of the upper level trough where the persistent boundary between the polar and tropical air masses lay. Much below normal temperatures were caused in the West by the strong northwesterly flow of cold polar air masses behind the upper level trough.

Inasmuch as these troughs can produce such outstanding weather abnormalities, the question arises as to whether their positions can be predicted. Some success has been achieved by working with five-day and monthly pressure averages, or mean charts, which mask short-period and small-scale fluctuations. These mean charts, like the longer-term normal charts, exhibit a wavelike pattern in the westerlies, and these mean, or average, waves progress around the hemisphere. With statistical and physical reasoning the motion and intensity of these upper level waves can frequently be gauged.

It should be emphasized that the long-range forecaster is concerned with broad atmospheric currents and average storm paths rather than with the motions of individual air parcels and the pressure systems of the daily weather map. For this reason long-range forecasts describe over-all weather conditions during five-day and monthly periods, and are not day-by-day accounts. It should also be stressed that mean troughs move much more slowly than the air particles themselves. During a two-year test period the average west-to-east speed of air particles and of daily troughs was found to be twelve degrees of longitude per day, whereas the speeds of five-day and monthly mean troughs are only of the order of one degree and one tenth of a degree of longitude per day, respectively. It is clear from these figures that air particles and daily systems move from west to east ten or one hundred times as fast as mean troughs. In other words, the particles are moving eastward *through* the mean troughs.

The primary factors governing the motion of mean troughs are believed to reside in the concept of the conservation of the total vertical component of absolute vorticity. From this it has been shown that the over-all strength of the west wind current around the hemisphere, called the zonal index, U, and the wave length, L, between troughs are highly significant. Thus, as shown in the first equation in Figure 2, the eastward speed of the trough can be expressed as $c = U - \frac{\beta L^2}{4\pi^2}$, where β is the rate of change of the Coriolis parameter with latitude and is a constant for any given latitude. From this expression it is seen that the eastward speed of the trough is greatest when the west wind speed is greatest and when the wave length is short (i.e., when L is small). The troughs may actually retrograde—that is, move westward—if the wave length is sufficiently long. The stationary state ($c = 0$) is shown in the second equation of Figure 2 where L_s is the stationary wave length. In the atmosphere, troughs are almost always in a state of motion, however, and are forever attempting to reach equilibrium.

Figure 3 shows the series of five-day mean 10,000-foot pressure maps prepared twice weekly during the two-and-one-half week period from April 9 to 27, 1941. A trough in the western United States moved fairly regularly eastward in its northern portions but very slowly in its southern portions; consequently, the trough was left behind over the southwest during the period. The reason for the failure of the lower portion of the trough to move is that the west wind currents in lower latitudes were becoming weaker and weaker and the westerlies at more northerly latitudes maintained a constant, fairly high strength, as shown by the pressure gradients. This trough shearing resulted in persistently cool weather in the southwest during the period.

The converse of shearing is shown in Figure 4, where two troughs, originally at different latitudes, combined into one as retrogression took place at northern latitudes while eastward motion was evidenced at lower latitudes. As in the previous figure, these charts are five-day mean pressure maps at the 10,000-foot level and are for the period from October 18 to November 9, 1941. From October 18 to 22 there was a mean trough in the central Atlantic. The long wave length at higher latitudes between this trough and the one in the eastern Pacific is especially noteworthy. Because of this

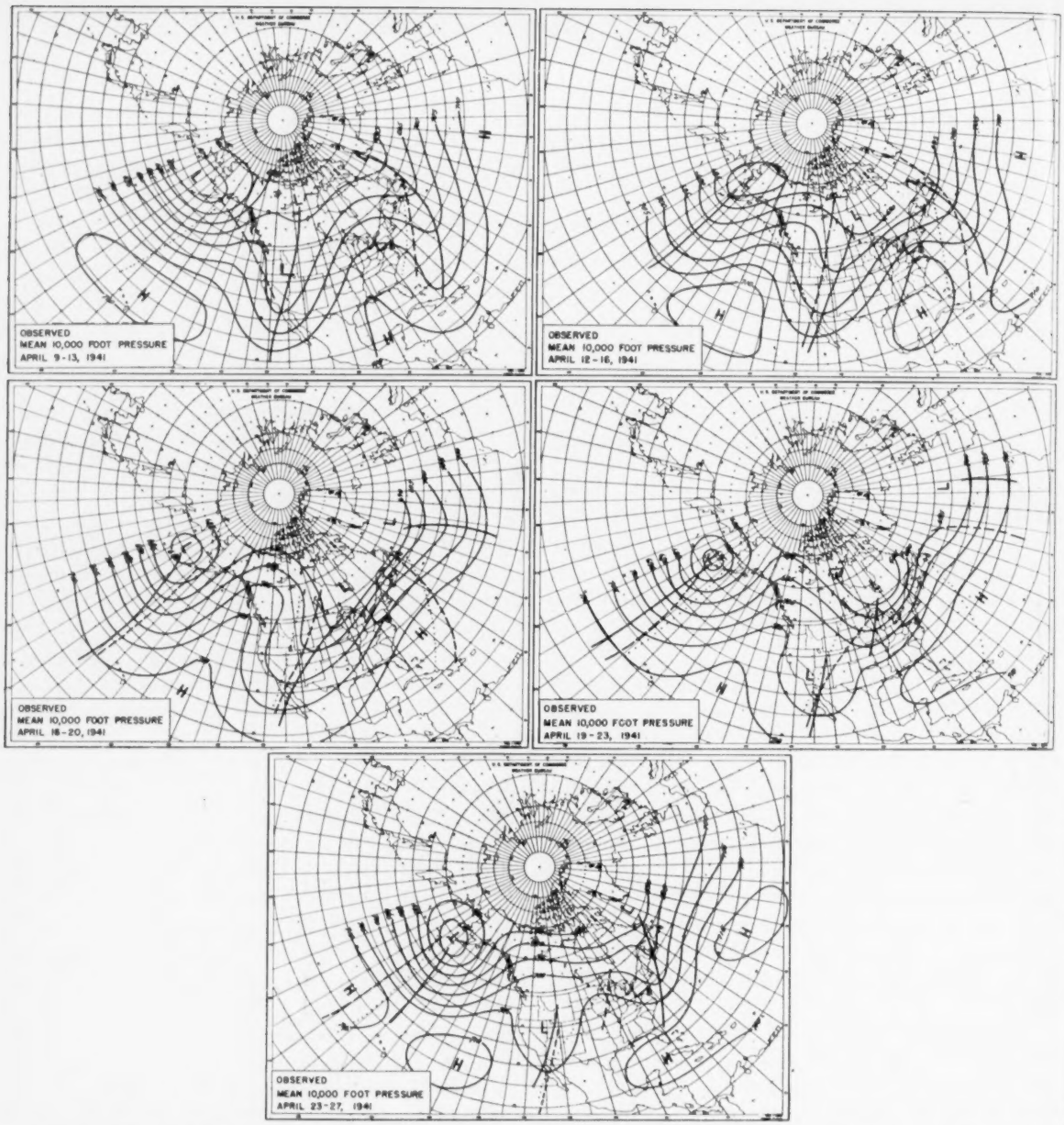


FIG. 3. Observed five-day mean 10,000-foot pressure patterns April 9–27, 1941. Trough lines (solid) are local loci of latitudinal pressure minima; dashes indicate trough positions one-half week previous, and dots show positions one week previous.

long wave length the trough backed to the east coast of North America on the succeeding map, and, by the period October 25–29, it moved still farther westward to the Great Lakes region. Meanwhile the low latitude trough over California began to make slow eastward progress and attempted to join with the trough over the Lakes during the period October 25–29. The following maps of the series show the two troughs combining as they led ultimately to the development during the period November 5–9 of one extensive trough from Hudson Bay to Yucatan. This combination in turn led to the transport of cold polar air masses far southward and extremely cold weather in the Gulf States.

These series of maps illustrate the primary requirement of forecasting the strength of the west wind currents around a large section of the Northern Hemisphere and then predicting the configurations of the isobars aloft. This affords a prognostic picture of the waves in the westerlies. The basis for forecasting the strength of the westerlies is essen-

tially statistical in nature in that it relies largely upon the serial correlation, or persistence, of this current, which seems to possess great inertia. Physical reasoning, such as the confluence, or flowing together, of air currents of different temperature characteristics, is also employed.

The prognostication of the upper air flow pattern is based largely on the trough speed formula as discussed, but with the application of empirical corrections for different latitude bands and for the seasons. In addition, various statistical and physical tools are employed. In particular, estimates of future heights and tendencies are obtained by regression methods, and subsequent motions of mean pressure systems are calculated by means of kinematic computations. The indications from the several tools are coordinated to arrive at a forecast of the upper air circulation.

Once the upper air pattern has been determined, a prognostic chart of the pressure pattern at sea

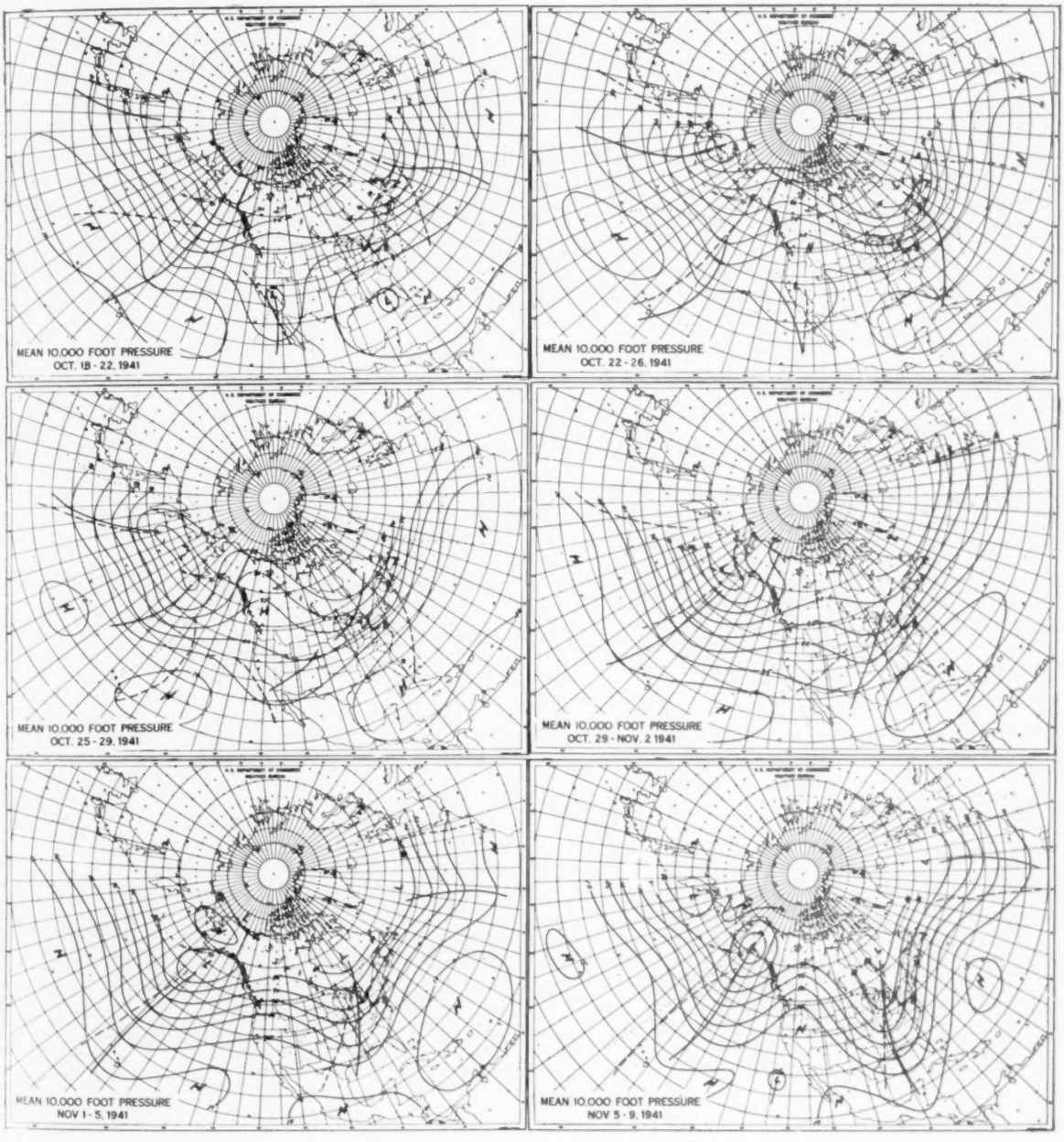

MEAN 10,000 FOOT PRESSURE
OCT. 18 - 22, 1941
MEAN 10,000 FOOT PRESSURE
OCT. 22 - 26, 1941
MEAN 10,000 FOOT PRESSURE
OCT. 25 - 29, 1941
MEAN 10,000 FOOT PRESSURE
OCT. 29 - NOV. 2 1941
MEAN 10,000 FOOT PRESSURE
NOV 1 - 5, 1941
MEAN 10,000 FOOT PRESSURE
NOV 5 - 9, 1941

FIG. 4. Observed five-day mean 10,000-foot pressure patterns October 18–November 9, 1941. Trough lines indicated as in Figure 3.

level is prepared. The predictions of activity at sea level, as well as forecasts of precipitation amounts and temperature departures from normal over the United States, are decided, for the most part, on the basis of the upper level prognosis. When completed the entire forecast must be internally consistent. Cold air may be trapped at high latitudes, for example, by a strong, narrow belt of west winds, called the jet stream. A falling zonal index is associated with a break in this fast westerly flow, and arctic air masses may then flow southward into the United States behind the upper air trough. Similarly, precipitation is usually found in the southerly flow ahead of troughs, the amount depending on such things as the intensity of the wave and the availability of moisture.

The forecasts of temperature are expressed in terms of departures from normal. On the basis of statistical studies of temperature records over the entire country at various times of the year, numerical limits have been established for different regions such that the classes much above and much below normal have each occurred in the past only one eighth of the time; near normal, above, and below normal have been defined so that the temperatures in each of those classes have occurred one quarter of the time. In like fashion, the terms light, moderate, and heavy are used for precipitation forecasts, each class having equal probability of occurrence. Obviously the values defining these classes vary from one place to another and from season to season. Temperature departures that are considered much below normal in southern California do not constitute much below normal in the Plains states, where temperatures are much more variable. Similarly, what is called light precipitation for the eastern Gulf states in winter would be considered as heavy precipitation in southern California.

Since the departure from normal of temperature is dependent on the direction and strength of the flow aloft, it is possible to measure this flow—or its departure from normal—and obtain objective estimates of the surface temperature anomalies. The effectiveness of one such objective scheme is shown in Figure 5, which compares the objective estimate of temperature departures from normal from the monthly mean charts for February 1946 and Feb-

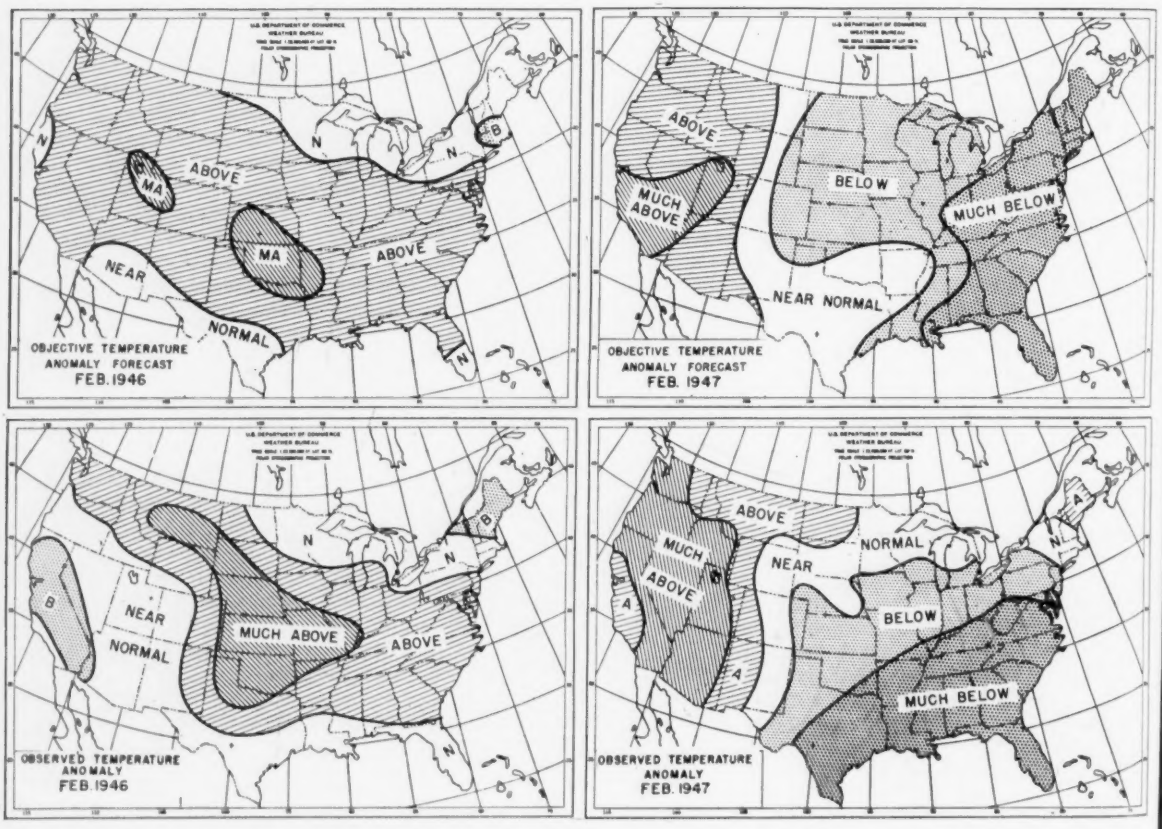


FIG. 5. Upper charts represent surface temperature departures from normal as interpreted by an objective method applied to observed upper level circulation patterns for February 1946 and February 1947. Lower charts are observed surface temperature anomalies for the same periods.

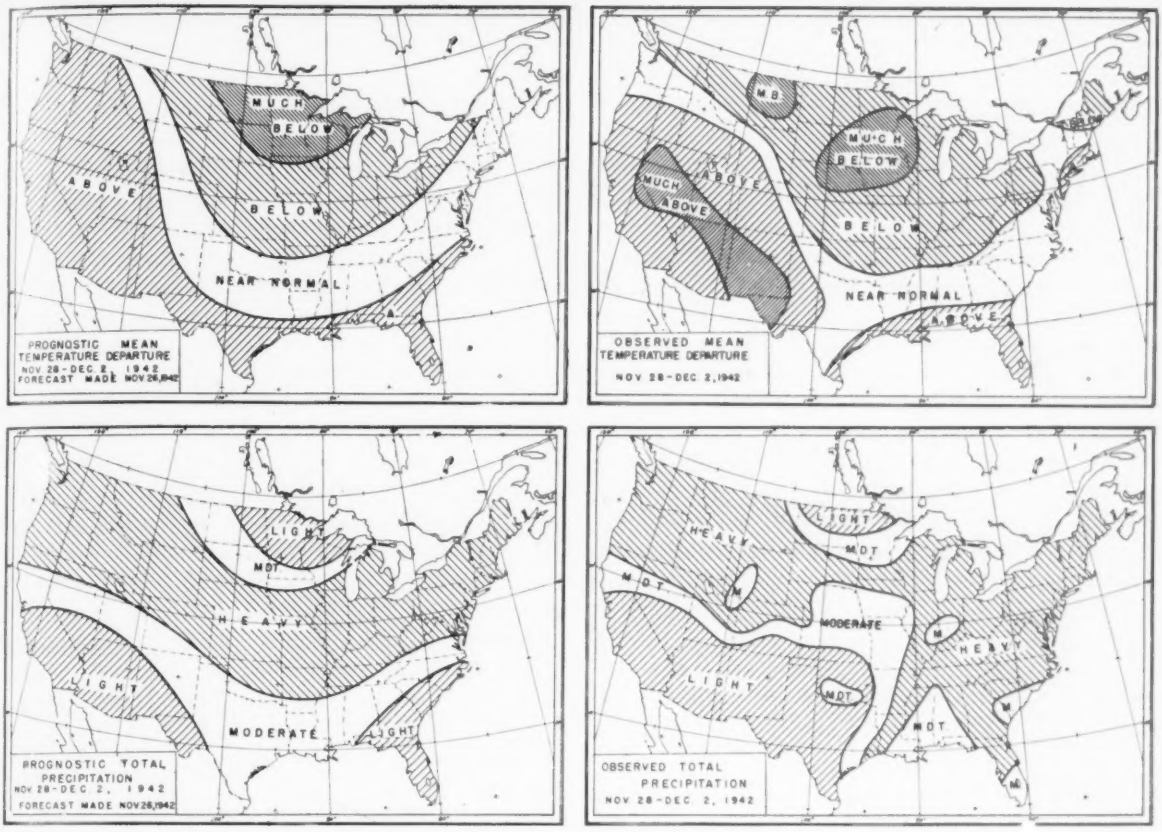


FIG. 6. Charts on left are forecasts prepared on November 26, 1942, for surface temperature anomalies and total precipitation amounts expected during the period November 28–December 2, 1942. Right-hand charts depict the temperature and precipitation patterns observed during that period.

ruary 1947 with the temperature anomalies actually observed.

With the aid of the objectively determined anomalies of temperature and the prognostic pressure patterns at sea level and aloft, the forecaster can predict where cold and warm air masses will predominate and also where the prevailing storm activity will occur. An example of a set of prognostic and observed temperature and precipitation patterns is shown in Figure 6. The upper charts show the forecast and observed temperature departures for the five-day period beginning 36 hours after the latest data available at the time of the forecast. The cold and extremely cold weather predicted for the Lakes region and northern and central Plains states was observed. Warm weather in the west and south was forecast and was also observed. It was, however, somewhat warmer than expected in some areas, where much above normal, rather than above normal, occurred. The precipitation patterns shown in the lower part of the figure reveal that heavy precipitation was expected to spread across the country from Washington and Oregon through the central Plains and eastern Lakes region to New England. In general the observed precipitation, shown in the lower right, bears out this pattern, although it will be noted that the forecast was in error in the southeast, where heavy and moderate precipitation occurred although only light had been predicted. It should be pointed out that this particular illustration is, on the whole, better than average.

In addition to the general temperature and precipitation conditions expected, an attempt is made to anticipate trends within the forecast period. For the five-day forecasts a set of six daily prognostic charts is prepared to show how the forecaster expects individual storms, high-pressure areas, fronts, and air masses to behave. The basis for the preparation of these maps lies in a judicious extension of the short-range forecast, using as a guide the mean prognosis arrived at by long-range techniques. The breakdown of the period into specific daily activity is without doubt the most unsatisfactory part of the forecast procedure. It is often possible to predict the general weather char-

acteristics of a period, but at the same time it may not be possible to give an accurate play-by-play description of the weather making up the period. In other words, forecasts for a picnic on a particular day five days ahead are not apt to enjoy a high degree of success. On the other hand, although the timing of weather sequences may be inaccurate, the over-all forecasts may be of considerable value to the farmer, hydrologist, coal distributor, waterways operator, and many others who are less interested in exactly when a special weather event will occur as they are in cumulative or average weather conditions over some particular period such as the coming week or month.

The users of long-range forecasts are a representative cross section of American activity, from farmers and fishermen to newspapers and electric power companies, from bakeries and baby food concerns to building managers and housewives—and also fellow-meteorologists. Decisions by canners and many others can only be made after a consideration of the long-range forecast. In the case of the five-day forecasts, the basic elements of the prognosis are transmitted by teletype and telegraph to the district forecast offices of the Weather Bureau. Here the district forecaster gives the most effective local interpretation to the forecast, and, utilizing the latest weather maps and reports, he is able to improve the timing of the anticipated weather changes.

In general, the progress to date in long-range forecasting has been limited by the scope of the problem, one of the most complex of any natural science. In addition, complete data on a historical as well as on a current basis are lacking, particularly from tropical regions and high altitudes. Even when this vast amount of data, necessary to obtain an understanding of atmospheric processes, does become available, we shall still have the problem of handling it—perhaps with the aid of new, high-speed electronic computers. During recent years an increased network of observations in the upper air over most of the Northern Hemisphere has made possible studies of weather interactions over long periods. These studies have shed light on the causes of some of our longer-period weather abnormalities and have suggested lines of attack that may eventually lead to a system of predicting weather anomalies for as far in advance as a coming season. Research along these lines is being carried on with vigor at many meteorological centers, although up to the present no reliable method of anticipating seasonal characteristics has been evolved.

What Constitutes a Polluted Water

A WATER is said to be polluted, according to Prof. von Pettenkofer, when it is no longer clear and inodorous, when fishes and plants perish in it, and when it contains more organic matter and less oxygen than are to be found in the unpolluted portions of the flow of the stream. Such contamination is essentially different from the transient turbidity due to heavy rains or to melting snow. Still, even the permanent pollutions disappear in the further course of the river bed, by deposition and other agencies. Here the rapidity of the stream and the quantity of the water exert a preponderating effect. The most formidable impurities are supposed to consist of the putrescent refuse which flows out of sewers of cities, and quickly produces an offensive odor at the places where it accumulates.

Prof. von Pettenkofer has for many years given his attention to the question of the extent to which rivers are polluted by such agencies, and has had researches conducted by his pupils. But nothing has hitherto altered the opinion which he expressed long ago, that sewage may be safely permitted to flow into a river if its volume is not more than one fifteenth that of the river water, and its rate of flow is decidedly greater than that of the current. Taking the city of Munich, which has 280,000 inhabitants, he computes the pollution of the Isar by its sewage as amounting to only 1/1,000,000 of the discharge of the river—a pollution so inconsiderable that it can not be detected by the eye when a corresponding mixture is made up experimentally. But it is also not permanent, for at Ismaning, seven kilometres below Munich, the sewage influx is no longer to be detected; and at Freising, thirty-three kilometres below, the chemical and bacteriological tests show that it has lost nearly all its power of pollution. Thus, the number of 198,000 bacteria per cubic centimetre found by Prausnitz at the mouth of the Munich sewer was reduced at Ismaning to 15,231, and at Freising to 3,602. A similar result was obtained by Frankel with the water of the Spree at and below Berlin. The mere number of bacteria found has, however, no sanitary significance, since these particular microbes are mostly harmless, and in fact destroy the pathogenic microbes in the struggle for existence.

The purifying action of rivers is ascribed by von Pettenkofer to the oxygen dissolved in the water in a free state or separated from organisms. In the latter respect the green algae and even nonchlorophyllic plants come prominently into consideration. This vegetation should be preserved; but it may be destroyed by a too great concentration of the water to be purified; and to prevent this, industrial waste waters which destroy vegetation must be kept out till they have been purified.—*The Popular Science Monthly,* **43**, 142 (1893).

Man, the State of Nature, and Climax: As Illustrated by some Problems of the North American Grassland

JAMES C. MALIN

The author, who took his Ph.D. in history at the University of Kansas in 1921, has been in the Department of History of his alma mater ever since. His intense interest in the ecology of the Great Plains has expressed itself in numerous articles in which he has discussed the various and shifting relations of man with his environment.

THE state of nature as it is commonly accepted is nonexistent. When man appeared upon the scene he destroyed such a state, because he possessed the unique capacity to act with a purpose. No matter how primitive, he introduced the factor of planning, and the element of choice. The length of time man has occupied the North American continent has been variously estimated. Prior to about 1930, the maximum was set at about 3,000 years. After that approximate date, the Folsom man discoveries led a large segment of anthropologists to reach back 40,000–50,000 years. The new carbon-14 test, applied at the mid-twentieth century, affords a new measuring device, the application of which, not yet complete, is constructing a new calendar, with 10,000 years as the probable maximum and Folsom man possibly near half that figure.*

The contention of this paper is that the botanist, zoologist, and the soil scientist cannot expect any real success in many aspects of their own disciplines, in an ecological sense, until some tangible achievement is made in dealing with the problem of man's influence. Such a necessary recognition of the role of man affords a common ground between them and the geographer and the historian. First, the nature of the problem of man, as an ecological factor, must be discussed and defined, in order to appreciate the full range of the ramifications involved. Once the significance of the problem is fully recognized, then, possibly, methodology can be formulated and techniques and tools devised that may achieve some exactitude of measurement, and thereby place the study upon a quantitative basis. If success attends such efforts, then the accumulation of necessary data will follow. All that can be attempted here is to undertake the first step of definition and discussion of the nature and scope of the problem as applied to a particular area of concentration, and some of its implications to all the disciplines concerned.

The true state of nature existed only prior to the emergence of man. The disciplines most concerned in the study of that time are geology and paleontology in their several phases. If the study of the state of nature as modified by aboriginal man is the center of interest, then to the two disciplines already mentioned must be added archaeology and anthropology, plant and animal ecology, geography, and soil and other sciences. It is history based upon human remains, or documents, prior to the invention of writing. If the focus of study is upon the occupance of the continent since European man arrived in 1492, the conventional conception of history derived from written documents is added to all the others. Of the three stages, the first deals with the true state of nature, the second with aboriginal man's modification, and the third with European man's modification. The first two involve a dual culture conflict, the last two a triple culture conflict. How can either regime of human occupance be determined and measured?

* Since this was written a further revision, involving a drastic reorientation, has been proposed by G. F. Carter (*Sci. Monthly*, **73**, 297 [1951]). The effect of his proposal is only to add emphasis to what is said here.

The speculative or philosophical status of most of the approaches to the problem of the North American grasslands under man's influence may be illustrated by a brief reference to the work of a number of distinguished specialists. Carl Sauer, a geographer, took an extreme view of aboriginal man's influence upon nature, attributing the grassland and the extinction of certain Pleistocene animals to man's use of fire.[1] His views carry great weight west of the Rocky Mountains. C. W. Thornthwaite also took an extreme view of culture control of environment, applied more particularly to European man in America. As the extensive erosion in the West was attributed by him to the influence of man, he held that the remedy lay in the same hands, especially by means of government planning. Because of his being in government service, his influence was widely disseminated by high-pressure official propaganda.[2] The position of Kirk Bryan was near the opposite extreme from Sauer and Thornthwaite, holding to the dominance of impersonal natural forces effecting climate changes sufficient to shift the balance of equilibrium on the side of erosion or introduce such instability that man's role was only a minor factor in the larger complex setting.[3] Under this interpretation, remedial measures by either private or governmental action were of limited benefit. Ellsworth Huntington occupied the extreme position also in maintaining climate determinism.[4]

In the field of plant ecology, F. E. Clements formulated a doctrinaire concept of ecological succession, climax, and disclimax, the last phase being charged particularly to the work of European man.[5] This theoretical construction had little realistic relation to such historical evidence as was available.

In the field of soil theory, C. F. Marbut and his associates and successors in the USDA adapted the highly doctrinaire Russian soil theory to the United States: The idea of profile and maturity as soil climax.[6] This stereotype also possesses doubtful value, except in a few limited spots, in understanding the problems of the grassland, where the soils are largely derived from transported materials, and disturbance is the most conspicuous characteristic of the environment. There is little room for the idealized view of the conservationist literature, that soil was derived from the disintegration of underlying rock as rapidly as stabilized erosion in a state of nature removed it at the top—a state of mythical equilibrium—until that state was destroyed by modern man. H. H. Bennett declared that the Missouri and Mississippi rivers ran clear during this "state of nature."[7]

George F. Carter offered the suggestion, relative to California aborigines and grasses, that the gathering of edible seeds aided in the dissemination and reproduction of some species, creating an artificial climax. The passing of the Indians and the invasion of Mediterranean rye were approximately coincident in time, and the elimination of the native grasses may have been the result of a cause-effect relationship.[8] O. F. Cook made the suggestion, revived by Higbee, that the dominance of the chicle forest in Maya areas of Central America reflects the deliberate protection of that species for its edible nuts.[9] Likewise, Carter and Higbee make a similar suggestion for the dominance of the oak-hickory-chestnut deciduous hardwood forest in the eastern mid-latitudes of the United States.[10]

As stated, all these interpretations are, in the scientific sense, unproved. They are in the nature of speculation, hypotheses, theories, philosophical assumptions—or whatever term most appropriately designates propositions that are not subject to scientific proof in the broad, general form in which the question is stated. Of course, many scientific data have been brought to bear upon them, and the scholarly standing of the men mentioned is such that much of their work stands the test, within limits. Is it possible, then, to formulate the essential questions in meaningful forms subject to proof?

The Problem of the Great Plains

Less broad than the propositions just stated is the problem of the so-called Great Plains portion of the North American grassland and immediately related areas. W. D. Johnson offered the first major interpretation of that area: that the Great Plains were the relatively undisturbed remnant of the apron of debris that had been washed down from the Rocky Mountains in the process of weathering. No rivers had cut through the Llano Estacado, but he viewed the mid-latitude section as having been dissected by such rivers as the Canadian, Arkansas, Smoky Hill, Republican, and Platte. Within the past two decades, however, the Johnson theory has had to be discarded as too simple. Geologists dealing with Nebraska and Kansas have arrived at the conclusion that the drainage system of these mid-latitudes has changed materially, possibly more than once, during the Pleistocene, and that the material has been eroded and redeposited accordingly. In other words, during Pleistocene time, the area was in a state of continuous disturbance under the influence of impersonal forces.[11]

Late in Pleistocene time man appeared, possibly 5,000–8,000 years ago, in the mid-latitudes (a

more exact dating may emerge from the carbon-14 method of measuring time). From that point, the purposive influence of man was added to the impersonal forces contributing to continuous disturbance in the area. Archaeological work and its interpretation by anthropologists have only begun in the grass country east of the Rocky Mountains, and in some areas only sketchy preliminary surveys have been made for some subdivisions. Since Folsom and Yuma man, several successive cultures have occupied the country, the extent, density, and persistence of which are only beginning to be understood. Archaeological evidence is lacking as yet to construct satisfactory maps of distributions and historical sequences of occupance. Sites have been located upon which successive cultures have been recorded in archaeological remains, one above the other, and separated by accumulations of wind-blown material.[12] These records are unmistakable evidence of continuous disturbance, both impersonal and human, upon the same site. Possibly a reasonably accurate dating, or calendar, of these occupations and of intervening abandonment may be constructed, and upon a sufficient number of sites, with a distribution wide enough to be really meaningful.

By narrowing down step by step in space and time, particular sites come into perspective, and the bridge can be built from the purely archaeological documentation to the written, the intervening transition involving both. The expedition of Coronado into the Great Plains in 1541 is such an instance, although for other spots dated events may be associated as accurately or more so. The route of Coronado and his terminus in Quivira have long been matters of dispute, but the most recent studies brought to bear upon the problem, utilizing both archaeological and written evidence, have agreed upon the Rice-McPherson County, Kansas, area as the most probable site of Quivira.[13] As these counties were settled by Americans during the 1870s, the period between Coronado and American settlement was about 330 years. The archaeological estimates of time indicate that the same culture that Coronado met persisted until the early eighteenth century, allowing a time span of about 150 years between the two occupations.

Since American contacts were established in the area, intermittent disturbances of considerable proportions have been conspicuous. For instance, dust storms were an integral element in the physical and ecological history of the country within the period of written record, and during the years that the only direct and tangible human influence was that of the nineteenth-century Plains Indian occupants. The missionary-surveyor Isaac McCoy described a typical dust storm, in what is now east-central Kansas, in the fall of 1830.[14] The printed record of dust storms, with particular reference to Kansas, has been compiled by the present author for 1850–1900.[15] These accounts do not describe the particular sites involved in the Quivira remains, but those village sites are within the area covered and were subject to the same general conditions that affected the region as a whole.

Movement of Soil

The definition and delimitation of the problem under discussion may be facilitated by an approach from another direction, followed by the necessary narrowing of space and time to pin-point the essential issue at stake. Taking the Mississippi Valley drainage basin as a whole, the records of the U. S. Geological Survey indicate that no greater quantity of water or silt passed Baton Rouge into the Gulf of Mexico in 1951 than when records began, upwards of a century earlier. The high water mark of the Missouri River flood of 1951 did not exceed the high water mark of the flood of 1844 at Boonville, Missouri. Such facts run counter to the assumptions of most conservation propaganda, but they are vital in evaluating the influence of human action upon the area as a whole as well as upon any particular spot. In spite of great damage to man's improvements in the valley, especially urban development in flood bottoms (which never should have been made in the first place), the great flood of 1951 in the Kansas Valley was of great benefit, by and large, from the standpoint of agricultural resources as reflected in improved productivity of bottom land. Serious erosion occurred in some uplands, and the gains must be balanced against the losses for the valleys as wholes. For the Mississippi Valley as a whole, or for the Kansas Valley as a whole, natural resources in terms of water erosion meant, primarily, only a movement of soil from one place to another within the valley, and not a dead loss.

The problem of wind erosion must be approached in similar fashion. Sand and dust are moved by the wind from place to place, but the net loss is negligible, and probably not greater than formerly—that is, prior to occupation by Americans within the century. According to the archaeological evidence, the thickness of the wind-blown material that interlayers successive aboriginal village sites would indicate greater dust storms by far than occurred during the decade of the 1930s. The movement of dust by air currents is continuous, but the meteorological service had not kept records and

had not devised instruments and techniques for recording the phenomena. During the still part of the night, dry dust fall is usually most conspicuous. A partly enclosed patio floor of the author's residence has afforded opportunity to verify dust fall; red, yellow, or black dust collected in measurable quantities repeatedly during the night, the color giving some indication of the probable place of origin. Repeated checking with the local weather observer and with published reports of near-by weather stations on such occasions has not revealed any record by them of such occurrences. Likewise, during the summer of 1951, when rain fell nearly every day, measurable quantities of dust fell with the rain. Water erosion moves soil from a higher to a lower position topographically, but airborne dust is deposited everywhere. The question for which there is no present answer is, How much? And neither is there an answer in exact measurements to the question, What is the net gain or loss from combined movements of soil materials? A further question should be entered in the record: Does this soil lose in its capacity to produce vegetation by being moved from place to place either by water or by wind? If the answer is always in the affirmative, then why is land in flood bottoms often greatly benefited by floods? If it is not lost in that case, then the burden of proof would seem to lie against the claim that it is always lost.

Aboriginal Cultures

It is a truism that archaeologists deal with excavations; one of their chief badges of office is a spade. But if all erosion carried soil to the ocean, they would have no remains of human culture to uncover. What are the sources of the cover, or overburden, under which the evidences of human occupation are buried? First is the accumulated matter derived from vegetation; second, if the site is on a slope, water erosion would wash material from higher points; third, dust fall derived from wind erosion would accumulate on high as well as on low spots, both dry and wet deposits.

One of the first men to publish descriptions of the Rice-McPherson County sites was John August Udden, a young Swedish teacher (later to become a distinguished geologist) at the Academy of Bethany College, Lindsborg, Kansas. In 1881, when he was twenty-two years of age, his students called his attention to the Paint Creek archaeological remains, and in his spare time he worked over a period of seven years at the site. His published report did not appear until 1900. He described two types of mounds, which he interpreted, respectively, as burial and dwelling sites. The burial mounds were "usually built on high bluffs or on upland hills." They were covered with earth and vegetation, and within them was "a pile or layer or rocks" under which were human remains. The mounds he called dwelling sites "do not occupy any conspicuously high places, but usually lie on or near some flat and fertile lowlands as on the border of an alluvial plain." They were really not mounds, he explained, "but merely flat surface of the ground where dwellings of an earlier race have once been standing. They would never be noticed, were it not for the relics of household art, chase, and warfare scattered about the place."[16] Wedel[13] denied that they were building sites. His verdict was that they were village refuse dumps, but for present purposes the original use is not at issue.

There is no exact dating either of the time of first or last occupance of the Paint Creek site, or of its duration. The accepted minimum of time elapsed since aboriginal abandonment and Udden's observations is about 150 years. The significant part of Udden's description is that "they would not be noticed, were it not for the relics." This would seem to imply that so far as soil and grass composition were concerned there was no apparent difference between the low, flat mounds and the intervening prairie. Upon digging through the mounds, Udden noted that upon reaching the prairie level, the ground was harder. Having lived in Kansas during a dry, dust-blown period of the later eighties, and as a geologist being professionally interested in wind-blown materials,[17] he attributed the mounds to dust accumulation around the houses. Even if we accept Wedel's interpretation of origin, the dust-and-sand-accumulation thesis would apply equally well. Outwardly, at least, the marks of men (scars?), representing possibly 200 or 300 years of occupance, had been erased within 150 years, except for some unevenness of the surface. The present author checked one of these sites with some care at two different times during the summer of 1951 and could find no evidence of surface variations in soil or vegetation that could be attributed to aboriginal occupation. The same aboriginal culture covered at least five or six central Kansas counties and extended down the east side of the Arkansas River valley at least as far south as Arkansas City, where some excavating has been done. These people lived by agriculture, cultivating advanced varieties of corn, beans, and melons, they dug native roots from the prairie soil, and they hunted wild game. Yet this area was always described by the first white settlers as virgin prairie, and by conservation enthusiasts as undisturbed by abuse at the hands of

man until white Americans broke the sod and upset the perfect equilibrium of the state of nature.

One of the overriding facts that has been kept in the foreground throughout this paper is the virtually continuous character of disturbance to soil and to vegetation during the whole Pleistocene and Recent time. The disturbance was the consequence of impersonal forces alone, physical and animal, prior to the advent of man, and to both impersonal and human purposive forces since. Without going to the extremes of Sauer, we may say that aboriginal man, through occupance over long periods of time, through agricultural pursuits, use of fire, killing of selected game, utilization of selected plants, and digging in the earth for root plants, certainly destroyed vegetation altogether in some spots of considerable size again and again, and interrupted succession of vegetation over wide areas where he did not destroy it. His selected utilization of animals and plants undoubtedly exercised an important influence upon the relative dominance not only of those particular species, but upon the whole range of interrelations of equilibrium throughout the grassland as well as in particular spots. Even though the nature of these influences have not been, and probably cannot be, reconstructed with any degree of completeness, the fact of such human influence cannot be denied or ignored. Even the nineteenth-century Plains Indians exercised a similar influence, in spite of the fact that their culture was substantially different from the culture of the people found by Coronado. In spite of such a record of destruction and interruption of succession, there existed a wide range in succession stages in the grassland, associated with a variety of conditions resulting from disturbances derived from natural forces of water, wind, and animals, and from planned action of man. The fact should be clear also, that certain kinds of damage done to nature by the action of man are more easily repaired than is usually recognized—and especially than is alleged by conservation enthusiasts, whether private or official. In other words, there are influences of human action upon nature that are quickly, and largely, if not fully, reversible.

The Quivira sites are only one instance of many that might be studied in a similar manner throughout the grassland. The archaeological materials that are accumulating for interpretation are so numerous and so new that one hesitates to generalize about the possibilities of correlating the archaeological evidence with the written documents. The point that is certain is that the reappraisal of the role of man must modify subtantially the prevailing views of the history of the grasslands.

The Soil Question

What corollaries or conclusions are to be derived from these facts? What other aspects of the study of the grassland must be re-examined in a fundamental fashion in the perspective of such a historical approach to the region? What is soil? How was it formed? And what span of time was involved? What of agriculture in the grassland under the long-term utilization essential to the support of the existing human culture? What of the proposed valley development of natural resources and conservation planning that has for some time occupied the spotlight of political controversy? Certainly some fundamental reconsiderations are in order. Why the haste to flood many of the sites of prior human culture before adequate investigations and interpretations of human occupance can be made? Why flood them at all, period? Once archaeological evidence is destroyed, whatever enlightenment might have been derived from it regarding the experience of man is irretrievably lost, and through the blunders of jockeying for current political advantage. Instead, it should be preserved in the interest of finding the most tenable solutions.

The limits of this article preclude any attempt to discuss the three major positions. Subjects two and three are offered only as suggestions, and the first, the soil question, is discussed only briefly and primarily in the spirit of inquiry to direct thought into fresh channels.

How can the idealized type of theoretical climax, either of soil or of vegetation, have culminated under the conditions of continuous disturbance established by history? The calendar of events does not allow the time necessary, 100,000 or even 10,000 years to produce five inches of topsoil as claimed by conservationists, or to complete succession and climax of vegetation for the area as a whole. Difference was more characteristic than uniformity. If this interpretation of facts is in error, then the concept of climax must be redefined, especially in its time requirement, both as respects soil maturity (climax) and vegetational climax. Furthermore, in that case, the implication that vegetational succession and climax are dependent upon progressive soil changes in the direction of maturity needs restatement or abandonment.

Does soil age have any relation to fertility or productivity? And, if so, what is meant by soil age? Is soil anything more than a medium, useful but not essential, to the growth of vegetation? How shall soil age be measured? To this last question there are three possible and quite different answers: First, by length of time in place sufficient to produce a well-defined profile according to the Rus-

Right, dust cloud obscures the landscape on Highway 59, south of Lamar, Colorado.

Below, an abandoned farmstead in Baca County, Colorado. Drifts of dust cover fences and farm buildings.

"One of the overriding facts . . . is the virtually continuous character of disturbance to soil and to vegetation during the whole Pleistocene and Recent time."

U. S. Soil Conservation Service photos

Right, two-story modern house, vacant for two years, is being covered by sand.

Below, in Swisher County, Texas, soil blowing from late-planted wheatfield piles up in roadside. Hummocks are 1–4 feet high.

"According to the archaeological evide
the thickness of the wind-blown mate
that interlayers successive aboriginal vil
sites would indicate greater dust storms
far than occurred during the decade
the 1930s."

U. S. Soil Conservation Service photos

sian-American school of pedology, with horizons A, B, C, D. Second, the length of time since initial weathering from rock, including the history of the weathered material as it may have been removed from place to place by action of water and wind. Does the weathered material gain or lose properties by such change of place? Third, the length of time involved in successive geological time periods—successive cycles of sedimentation, consolidation, and erosion down to the present. This last point is illustrated and emphasized sharply by inferences that the writer draws from studies of the selenium problem and of trace elements. In undertaking to explain the high concentrations of selenium in the soil at some points in South Dakota and Wyoming, Trelease and Beath advance the view that the selenium in the Cretaceous rocks was probably derived from the magma, or molten rock, exposed in Rocky Mountain formation; that Tertiary formations were derived from reworked Cretaceous strata, and thereby selenium became more highly concentrated; and that modern concentrations are a further development of the process, aided by certain plants that serve as selenium accumulators.[18] To what extent is selenium only an unusual example of the problem that is involved in all soil evolution, a problem that must be recognized in any attempt to explain the presence or absence of particular properties in any soil?

An evolutionary approach to soil theory is posed from another direction by the deficiency of some soils in trace elements. This problem appears to arise in connection with (but not exclusively) soils derived predominantly from shales and sandstones rather than from marine limestone deposits. After World War II, Kansas established an experimental substation in the southeastern part of the state to study the problem of such soils, of crop production upon them, and of feeding animals upon those crops. As with the selenium problem, which represents the presence of undesirable elements, the absence of desirable elements introduces questions of human nutrition.

In the low rainfall areas of the grassland, the soils are derived largely from transported materials, largely wind-blown, and other parts from water-worked materials modified by the wind; the same is true of the bottom lands of the valleys in the higher rainfall areas. This fact is emphasized for Kansas by R. I. Throckmorton's soil map, constructed before the subject was confused by later theories of pedology.[19] In some limited areas of low rainfall in the west, and in larger areas in the higher rainfall eastern portion of the grassland, the soil has been formed in place, and is the residual product of soil formation that seems to fit approximately into the diagrammatic formula of the Russian-American school of Marbut and his successors. Between the soils that shift rapidly under the influence of wind and water and the predominantly residual-type soils are all possible variants, with repeated disturbances under the influence of wind, water, and man, both aboriginal and contemporary, prominent in their history. Man's influence upon the total situation may easily be exaggerated; likewise, the influence of aboriginal man may be ignored under the influence of egocentric twentieth-century man. Both these perversions of history and science have occurred, and most of the literature available is vitiated by one or the other—or both—these errors.

In an area as varied as the grassland of North America, each spot must be evaluated in its own right. On soils derived from transported materials, which are of substantial thickness—and these occupy much of the low rainfall grassland—the topsoil may be eroded by wind or water down to plow depth, not merely once but several times, without impairing the productivity of the land. E. W. Hilgard, who did the most fundamental thinking about soils that has been done in America, pointed this out for arid soils of California in 1892.[20] Farmers in the grassland in question have learned this unimpaired capacity from long experience, and have compelled reluctant scientists to recognize it.

In the study of soil, why should there be exaggerated emphasis upon soil maturity in terms of profile? Has profile, per se, any necessary significance, and if so, under what limited circumstances of place and associated situation? An evolutionary or historical approach to soil formation reaches back in time beyond the range of such oversimplified stereotypes.

Obviously, the North American grassland has supported a succession of human cultures over a long period of time. You say the present one is different? Yes, but so were each of the others different from what had gone before. Beware of the egocentric present-mindedness of the dominant thought of the mid-twentieth century! Beware of its arrogance and intolerance! Not only of its arrogance, and intolerance of all contemporaries who differ with it, but of its attempt to escape from history by ignoring or ridiculing the past. Time is a ruthless judge and, in the end, Time has the last word.

A large part of American research funds and energy is expended upon technological research of a short-term character to achieve functional

ends, often primarily for political advantage. In the past, the basic thinking of the modern world has been done almost exclusively by Europeans. Two world wars have destroyed Europe physically, but what is critical is that Europe offers no recognizable evidence that it has the vitality to revive its capacity to think creatively. And no Marshall Plan, or any other artificial stimulus, can perform that miracle. Neither is there any present recognizable evidence that either the United States or Russia has the capacity to assume the responsibility for the fundamental thinking they have helped to destroy. Government funds, foundation funds, university funds, poured out to any Johnny-come-lately for "quickie research," cannot meet the challenge. Fundamental results cannot be produced in a summer, a year, or two years, with progress reports semiannually, or annually, to be reviewed by administrative authority to determine whether results justify renewal of support for another term. Creative thinking may require the sacrifice of a lifetime, and expectations for the requisite basic thinking must be geared to the cumulative power of generations of untrammeled effort, a situation now virtually nonexistent. The intrinsic problems of grasslands everywhere await a more comprehensive body of thought of this order of potentiality and action.

References

1. Sauer, C. *Geogr. Rev.*, **34**, 529 (1944).
2. Thornthwaite, C. W., Sharpe, C. F. S., and Dasch, E. F. *Climate and Accelerated Erosion in the Arid and Semi-Arid Southwest, with Special Reference to the Polacca Wash Drainage Basin, Arizona.* USDA Tech. Bull. 808. Washington, D. C.: GPO (May 1942); Happ, S. C., *J. Morphol.*, **5**, 338 (1942).
3. Bryan, K. *Ann. Assoc. Am. Geogr.*, **31**, 219 (1941); ———. *Science*, **62**, 338 (1925); ———. *New Mexico Quart.*, **10**, 227 (1940); Whittlesey, D. *Ann. Assoc. Am. Geogr.*, **41**, 88 (1951).
4. Huntington, E. *Civilization and Climate.* New Haven, Conn.: Yale Univ. Press (1915); ———. *Mainsprings of Civilization.* New York: Wiley (1945).
5. Clements, F. E. *Plant Succession: An Analysis of the Development of Vegetation.* Washington, D. C.: Carnegie Institution, Pub. No. 242; Clements, F. E., and Shelford, V. E. *Bio-ecology.* New York: Wiley (1939).
6. Marbut, C. F. *Soils of the United States.* Part III, *Atlas of American Agriculture.* Washington, D. C.: GPO (1935).
7. Bennett, H. H. *Soil Conservation.* New York: McGraw-Hill, 1–3 (1939).
8. Carter, G. F. *Sci. Monthly*, **70**, 73 (1950).
9. Cook, O. F. *Annual Report, Smithsonian Institution.* Washington, D. C.: GPO, 481–97 (1903); Higbee, E. *Geogr. Rev.*, **38**, 457 (1948).
10. Higbee, E. *Op. cit.*; Carter, G. F. *Op. cit.*
11. Johnson, W. D. *Twenty-first Annual Report, U. S. Geological Survey*, Part IV. Washington, D. C.: GPO, 609–741 (1899–1900); *Twenty-second Annual Report, U. S. Geological Survey*, Part IV. Washington, D. C.: GPO, 635–69 (1900–1901); Flint, R. F. *Glacial Geology and the Pleistocene.* New York: Wiley (1947); Condra, G. E., and Reed, E. C. *The Geological Section of Nebraska* (2nd ed.). Lincoln: Nebraska Geol. Survey, Bull. 14 (1943); ———. *Correlation of the Pleistocene Deposits of Nebraska.* Lincoln: Nebraska Geological Survey, Bull. 15 (1948); Frye, J. C. *Trans. Kansas Acad. Science*, **49**, 71 (1946); Colbert, E. H., *et al. Bull. Geol. Soc. Am.*, **59**, 541 (1948); Flint, R. F., *et al. ibid.*, **60**, (9), (1949).
12. Wedel, W. R. *Trans. Kansas Acad. Science*, **50**, 16 (1947).
13. ———. *Explorations and Field-Work of the Smithsonian Institution in 1940.* Washington, D. C.: GPO, 71 (1941); ———. Smithsonian Inst. Misc. Coll. **101**, (7), (1942); ———. *Trans. Kansas Acad. Science*, **50**, 16 (1947); Bolton, H. E. *Coronado, Knight of Pueblos and Plains.* Albuquerque, N. Mex.: Univ. of New Mexico Press (1949).
14. Barnes, L. *Kansas Histor. Quart.*, **5**, 364 (1936).
15. Malin, J. C. *Ibid.*, **14**, 129, 265, 391 (1946).
16. Udden, J. A. *An Old Indian Village.* Rock Island, Ill.: Augustana Library, Pub. No. 2, 10 (1900).
17. ———. *The Mechanical Composition of Wind Deposits.* Rock Island, Ill.: Augustana Library, Pub. No. 1 (1898); ———. *The Cyclonic Distribution of Rainfall.* Rock Island, Ill.: Augustana Library, Pub. No. 4 (1905). (Udden's later career was identified primarily with Texas and included the study of oil and gas geology.)
18. Trelease, S. F., and Beath, O. A. *Selenium: Its Geological Occurrence and its Biological Effects in Relation to Botany, Chemistry, Agriculture, Nutrition, and Medicine.* New York: Authors (1949).
19. Throckmorton, R. I. *Twenty-eighth Biennial Report of the Kansas State Board of Agriculture*, 33, 91, 100–101 (1931–32).
20. Hilgard, E. W. *A Report on the Relations of Soil and Climate.* USDA Weather Bureau Bull. 3. Washington, D. C.: GPO, 19 (1892).

FOUR POEMS

EDEN ON MY WINTER WINDOW

This morning, on my window,
a carboniferous garden glitters
with giant ferns and mosses
and swamps with dragonflies
etched in crystal splendor.

Here, in this frost-brocade,
my eyes discover Eden
before one of my kind
exulted there. I gaze in wonder.

IDA JOSEPHINE BRITTAIN

CAPACITY

How futile try to estimate
  what the heart can bear;
simpler far to gauge the weight
  of the summer air.

Its capacity for grief
  unto itself unknown,
that breaks beneath a fallen leaf,
  that lightly bears a stone.

MAE WINKLER GOODMAN

LIGHT OF SUN

The large and silver gash of light, sky-borrowed,
Flows like a river, works into the ground
With many separate labors we may guess.
It lies between us; breath of leaves moves out,
And mica glinting, grass, and tiny flower-heads.
If it were not for light, it would be shadow,
And there would be nothing, not even you,
Your warmth, the way you smile, and work with words.
The sun is in your thought, even in shade,
And in me also. Veins have borrowed light,
Sunlight that sped the icy rungs of space:
And here across the garden where we look,
Two shades of trees and people bear the light.
The sun still lies between but not for long.

DANIEL SMYTHE

ANSWER FOR GRACE

. . . pure mathematics not only extends our knowledge of nature, by enabling us to follow illuminating perspectives, but in insisting on relevance it helps to maintain the conditions of sanity.

—MORRIS RAPHAEL COHEN, *Reason and Nature*

Death is the numbers' eye:
addition's sum, subtraction's minuend,
from whose shadow we may multiply
the darkness, and divide the night
into the integers of dreaming and of sight.

MARTIN S. DWORKIN

Organization of Research in Africa*

E. B. WORTHINGTON

The author has been scientific secretary to the Colonial Research Council since 1946, following a distinguished career in the zoological sciences. After graduating from Gonville and Caius College, Cambridge, he went on a three-year expedition to the African lakes, was for a time scientist fo rthe African Research Survey, and for ten years director of laboratories and secretary of the Freshwater Biological Association, Wray Castle, Ambleside. In collaboration with his wife he has published a number of books on African science.

SCIENCE can be organized in two different ways, typified by the academic method on the one hand and the government method on the other. The academic method consists of picking a really good man and unleashing him. If his own ideas on a subject for research are too fluid one may suggest some problem, and then he is left to work out his own salvation. His professor may have a chat with him once or twice a term and, insofar as possible, provide him with the apparatus and facilities for which he asks; but he is in fact largely his own director. If he succeeds in his first piece of research, he probably goes from strength to strength in a research career; if he fails he is well advised to give up research.

The government method is the opposite. After an appropriate number of committees has decided that a particular investigation is needed and other committees have made available the requisite funds, search is made for a man to do that particular job within an agreed program. If the right man for the job cannot be found, a near miss is appointed. If he succeeds he is apt to line up for promotion to other jobs involving more responsibilty but perhaps less research; if he fails he is apt to go on failing.

Admittedly that is a caricature of the differences between the two methods, but we all know that the academic method of free research tends on the whole to produce the better results, and sometimes they turn out, unexpectedly, to be of outstanding economic importance. We also know that within a government system the other method is necessary, and that in Africa we generally have to find a man for the job rather than a job for the man. One of the problems of organizing research in Africa is to combine the two methods in such a way that we have the best possible conditions to produce really good results within a suitable scientific, administrative, and financial framework.

A large part of the organization of research has to be done by scientists themselves, by men who have personal experience of conducting research and can take the individual worker's viewpoint into perspective when reaching decisions. This means that a good number of scientists have to devote themselves to administration: they soon forget what a microscope looks like, and some of them shuffle papers for the rest of their days. Unfortunately, in the colonial system of early retirement, this change from looking down microscopes to shuffling papers tends to happen to scientists just when they reach the height of their powers in conducting research. Therefore another of the problems of scientific organization is to reduce to a minimum the number of good research men turning into administrators. Some of them have to, because the scientist and the administrator are partners in this picture. The old adage that the scientist should be "on tap but not on top" is becoming outmoded.

Most forms of science in Africa have to be closely related to development. It is often questioned, not only informally, but sometimes even in legislative councils, why we require all this science. It is pointed out that development has taken place for many years without much scientific background; there is little money to spend except on forms of development that can actually be seen on the ground; and, in any case, if we must have science, we want to see practical results, not a lot of people working in laboratories. The answer to such questions is of course quite simple: much development in the past has taken place in the wrong way and has been unduly expensive because there was insufficient knowl-

* Based on an address before the Nairobi Scientific and Philosophical Society on April 10, 1951.

edge, or the knowledge was not readily available at the time decisions were made; and, furthermore, the more development takes place the greater the crop of problems it throws up of a kind which only scientists can solve.

The assistance which governments give toward development can be divided into three main categories: First, productive services, including geology and mining, water supply, agriculture, animal industry, forestry, fisheries, and secondary industries, and also control of tsetse flies and locusts, which are two of the main factors limiting production; second, social services, including medicine, education, social welfare, and labor; third, what we can call "common services," which provide both for production and social progress. Here we may include administration, law, defense, police, transport and communications, building, electricity, urban development, printing, and a number of lesser services. In almost every one of these, science has an ever-growing part to play, and our organization for research must, insofar as possible, cover them all.

Under the strict limitations of finance and staff, priorities must be selected. In Africa production from the soil and water has to produce the primary force which sets the whole economic and social system in motion; it has to provide most of the funds for nearly all government services and a large part of commerce and industry—and it has also to feed many millions of people. It is right, therefore, that the main scientific effort should at the present stage be directed toward increased production, particularly agricultural, forestry, animal industry, fisheries, and also minerals.

Concerning the social services, most research at present is concerned with health and medicine, but sociology is a growing science in Africa, and some forms of psychology under the heading of "personnel research" have already become important in South Africa. Sociology and anthropology are highly important also in relation to native administration and law. Communications, especially roads, need a lot of investigation and scientific control, and the same is true of the building industry. Economic research, including demography and the statistics on which it is so largely based, has to pervade the whole.

In sketching the present organization of science in Africa, I shall restrict myself to the continent south of the Sahara. Admittedly that is a vague barrier, although one which from the biological standpoint separates the Ethiopian region from the Mediterranean. From other viewpoints also, the Sahara is a more satisfactory boundary than the Mediterranean.

South of the Sahara are some twenty-five separate countries with their separate governments. These many countries, however, with one or two small exceptions, are ultimately responsible to four metropolitan powers in Europe—the United Kingdom, France, Belgium, Portugal—and two in Africa—the Union of South Africa and Southern Rhodesia, the latter being almost entirely responsible to itself.

In all these African territories there is a natural tendency toward a degree of scientific independence from the home countries, so that institutions and organizations are growing up in Africa. Fortunately, this is tending to take place on a regional rather than a purely territorial basis, so that we can recognize nine scientific regions. Taking the British first, there is East Africa, including Zanzibar, and with connections with Somaliland and the Seychelles, Central Africa, including the Rhodesias and Nyasaland, and British West Africa which is inconveniently in four isolated units. The Union of South Africa, including South West Africa, and for scientific purposes the Protectorates also, is of course a scientific region of its own and far more advanced than the rest. Portuguese East and West Africa are best considered as one region, although widely separated from each other. The Congo and Ruanda Urundi are reasonably self-contained and form another. The French colonial territories, like the British, have to be thought of as three more or less separate regions, Afrique Occidentale Française, Afrique Equatoriale Française, and Madagascar. If we include the Anglo-Egyptian Sudan, that forms a tenth region which, though of special scientific importance, I am omitting from this sketch. I shall also omit Ethiopia and Somalia. These are not, of course, natural scientific regions. Except for a few subjects, however, they are the best we can achieve as organizational units at present, taking political and administrative factors into consideration.

As to the organization of research in each of these regions, since the regional conception is more fully developed in British East Africa than in some of the others, through the agency of twenty-five years of the East African Governors' Conference followed by three years of the East Africa High Commission, let us start with that.

The Ormsby-Gore Commission of 1924 and the Hilton-Young Commission of 1928, in considering the possibilities of closer union in East Africa, laid emphasis on the need for cooperation in research and science between the several territories. On a broader scale the Hailey Survey of 1934–37 pointed to the same principle, but also, by drawing comparisons between one region or territory and another, showed the need for much closer cooperation

among the several European powers responsible for Africa. These general questions have been pursued in a number of more recent commissions and reports.

Meanwhile, in East Africa, up to the outbreak of Hitler's war, touch was maintained in the fields of medicine, veterinary work, various branches of agriculture and the like by periodic discussions among directors of technical departments and specialists. The only scientific departments with truly interterritorial functions were the East African Agricultural Research Institute at Amani, which had been established in the middle 1920s on the foundations laid by the Germans before the 1914–18 war, and the East African Meteorological Department, which was developed as an interterritorial service in 1929, stimulated by the need to connect under a single organization a series of stations along the imperial airways route. In addition, however, the Tsetse Department of Tanganyika, based on the laboratories at Old Shinyanga, was conducting research designed to serve the needs of Kenya and Uganda, as well as Tanganyika, and the Veterinary Department of Kenya based at Kabete was performing similar functions in veterinary research and the production of sera and vaccine.

Difficulties occasioned by the war caused the isolation of research workers and of technical departments to become more acute, but meanwhile the opportunities for expansion and the establishment of interterritorial scientific activity were much enhanced by the Colonial Development and Welfare Acts of 1940 and 1945, followed by the establishment in London of a number of scientific committees and councils advisory to the Colonial Office. The organization of research in East Africa was much discussed toward the end of the war, so much so that attention tended to become focused more on organization than on the few workers who were engaged in actual research.

From 1944 until 1947 a number of visits to East Africa and conferences began to clear the air and prepare the way for establishing truly interterritorial research in a number of subjects. The procedure was generally as follows: some scientist or group of scientists from the United Kingdom came for a visit to study the position in East Africa and make proposals. In a number of cases a conference of territorial representatives and specialists met to consider the proposals before the departure of the visitors. These led to applications from the East African Governors' Conference for money to be voted as research grants from the Colonial Development and Welfare Fund. The first new research service to be established by this means was for inland fishery research, and in this case the whole capital and the whole recurrent costs for a period of five years were provided. Later the secretary of state insisted that a proportion of the recurrent funds in most of our organizations should be provided by the East African governments. There are still certain research schemes operating in East Africa wholly financed from C. D. and W. funds, but in such cases the research is intended to serve the needs of the whole colonial empire, and is based in East Africa as the region in which the work can be done most efficiently. Meanwhile, all the East African territories had prepared development plans covering a ten-year period, and these enabled a plan to be drawn up in 1947 for interterritorial research services to meet the needs of the rapidly developing communities.

The years 1947–50 have been devoted to putting into effect parts of that plan as opportunity offered, in close association with the system of committees, advisers, and the Research Department at the Colonial Office. A scheme for each research organization or service, including its progressive development over a period of ten years ahead, was sketched out, but firm estimates were prepared only for the capital and recurrent expenditure required during the first five years. When the finances for this initial five-year period were assured, a director was appointed, and subsequently the establishment or rearrangement of that particular organization has been left largely to him in consultation with territorial departments on the technical side, and the offices of the East Africa High Commission on the administrative side.

A good part of the research effort has continued and in some cases expanded in territorial departments. The line of distinction between interterritorial and territorial research is sufficiently defined by saying that the more fundamental and long-term projects are interterritorial, and the more technological projects are territorial.

Now that we have a number of interterritorial services, it is not claimed that the difficulties have come to an end. Indeed, once a research organization has come into being the financial limitations and the need for consultation in a multiplicity of directions have often magnified the difficulties. But, looking at the picture as a whole, there is at least a scheme of things.

There are now some 15 interterritorial services mostly concerned primarily, and many of them wholly, with research. Some are large, like E.A.A.F.R.O. and E.A.T.T.R.R.O., and they range down to one-man shows concerned with subjects such as leprosy. A summary is given in Table 1 which in-

TABLE 1

SUMMARY OF EAST AFRICAN REGIONAL SCIENTIFIC SERVICES
(Based mainly on E. A. High Commission Estimates for 1951)

	"Qualified" Officers (Percentage of Whole)	Recurrent Expenditure (Percentage of Whole)
Agriculture and Forestry (E.A.A.F.R.O.)	18	13
Veterinary (E.A.V.R.O.)	6	5
Tsetse and Trypanosomiasis (E.A.T.T.R.R.O.)	15	17
Locusts (Desert Locust Survey)	6	13
Insecticides (Colonial Insecticides Unit)*	5	6
Fisheries (Inland Water Research, Marine Research, and Lake Victoria Fisheries Service)	9	7
Industrial Research (E.A.I.R.B.)	5	4
Health and Medicine (E. A. Bureau, Filariasis Research, Medical Survey, Malaria Unit, Virus Research Institute, Leprosy, Relapsing Fever)	16	9
Sociology (E. A. Sociological Research Institute)*	6	3
Meteorology (E. A. Meteorological Department)	7	15
Statistics (E. A. Statistical Department)	6	7
Scientific Secretary	1	1
	100 (= 158)	100 (= £662,000)

* Not E. A. High Commission.

cludes the social research institute attached to Makerere and the Colonial Insecticides Unit, although these two are not responsible to the High Commission. The Statistical Department is included, also, although strictly speaking it comes under the heading of economics rather than science. To support the work of one qualified officer, including his assistants, facilities, and overhead, costs from under £2,000 in the case of sociology, to over £9,000 in the case of the Desert Locust Survey. These two extremes of course involve utterly different kinds of work and facilities. The over-all average is a little over £4,000 per scientific officer.

Looking into the distant future, the time may come for an all-embracing scientific and technical service for East Africa, implying regional instead of territorial technical departments in a number of subjects. But so long as the territorial governments themselves are separate, it is essential for most of the executive side of scientific work to be arranged territorially. The advisory side of science, however, and the research and investigation necessary for good advice, can often be arranged interterritorially with much advantage. Therefore, these regional services are limited for the most part to advisory functions and all that is entailed thereby. There are one or two exceptions to this: for example, the Desert Locust Control, a very large but we hope temporary growth closely attached to the Desert Locust Survey (not included in Table 1), the practical work of tsetse reclamation which is included in the functions of E.A.T.T.R.R.O., and the Lake Victoria Fisheries Service.

For comparison with East Africa let us look westward to the Belgian Congo. Until about fifteen years ago research there was arranged on the departmental system somewhat similar to that in East Africa prior to the High Commission. There was a difference, however, in that the great mining companies were largely responsible for big areas in which they operated, and they themselves organized a lot of scientific work, not only in geology and mining but in social and other services as well. About 1935 I.N.E.A.C. (Institut National pour l'Etude Agronomique du Congo Belge) was established: it deals with all agriculture, forestry, and animal industry research, and corresponds in fact more or less to our E.A.A.F.R.O. and E.A.V.R.O. combined, but in addition I.N.E.A.C. deals with a good deal of the scientific control of agriculture, which in East Africa is undertaken by territorial departments. I.N.E.A.C. has been followed since the war by the establishment of I.R.S.A.C. (Institut pour la Recherche Scientifique en Afrique Centrale), which deals with many forms of research other than agriculture. It takes within its purview, for example, geophysics, astronomy, biology, and sociology. Both I.N.E.A.C. and I.R.S.A.C. are separate foundations, with their money voted by separate acts of parliament, and under boards of governors which sit in Brussels. They are much more autonomous than British organizations in East Africa, and they have a great deal more money at their disposal. In East Africa the provision for research, including all the money coming from Colonial Development and Welfare funds, amounts to between 2 per cent and 3 per cent of the total public expenditure. I.N.E.A.C. alone in the Belgian Congo has about 4 per cent of the total public expenditure in that country. In I.R.S.A.C., by the way, the academic method of research is applied more freely than in East Africa, and there are cases in which a

job of research has been found in the Congo for a really good man, rather than a man for the job.

Turning now to the Union of South Africa, again, we find that it has been recognized, though only quite recently, that the kind of organization required for good research is rather different from that required for executive work. On the government side the main organization today is the C.S.I.R. (Council for Scientific and Industrial Research), which has developed since the war. It receives its funds direct from Parliament and is responsible directly to the Prime Minister. Its activities are controlled by a council composed of scientists and economists, with a scientist as president and chief executive. C.S.I.R. does not by any means control all science in the Union. It deals particularly with physics, chemistry, and the engineering sciences, also applied psychology, medical research, and fundamental biology. It does not do research in the agricultural subjects—which remains a function of the Agricultural Department in concert with the many agricutural colleges—nor in forestry, geology, mining, or the social and economic sciences. The Union has also, of course, the advantage of a great deal of research undertaken by the universities. The main point to note, however, is that in South Africa, as in a number of the colonial regions, we see the changeover taking place from the departmental system to organization of research designed to get the best results from research workers.

Passing to the French regions, we see something rather different. A good deal of research is arranged on the departmental basis as with us, but the French colonies, and indeed the Belgian also, have relied more than the British on the direct interest of the universities and centers of research in Europe, so that much research done in those countries in the past was in the form of expeditions of a year or so by scientists from home. Indeed, in 1933, when I was touring Europe, I found a great deal of interest in the French and Belgian universities, and many of the staff had actually worked in Africa. In the British universities, on the other hand, it was rare to find a professor or lecturer who had any knowledge of or interest in the African colonies. The French also, however, have recognized that proper scientific institutes in Africa itself are necessary, and there is now an important one in each of the three regions, the Institut d'Afrique Noire at Dakar for the A.O.F., the Institut d'Etudes Centrafricaines at Brazzaville for the A.E.F., and the Institut de Recherches Scientifiques in Madagascar. Each deals with a wide variety of subjects in the scientific field, ranging from mapping through biology and geology, to medicine and sociology. But the principle of close contact with the metropolitan scientists is maintained, because each of these directors is also a professor in France and spends a good part of each year in that country.

Of the Portuguese region I am not yet competent to speak, but the impression one gains is that much of the scientific work is still based on Portugal, although important institutes are growing up in Africa—for example, in Angola.

There remain the two other British regions of Central and West Africa, where considerable effort has been made to establish the regional organization of research on lines in some way similar to those adopted in East Africa, but the system has not yet reached an advanced stage. In Central Africa the main difficulties have, I think, been political, and although they had a scientific secretary for several years, and he wrote a competent report on the subject, the difficulties were so great that few of the recommendations could be adopted. In British West Africa the geographical isolation of the units has been a main difficulty, but a flourishing tsetse and trypanosomiasis research organization based in Nigeria was opened this year to serve the whole region, and a good deal has been done by way of interterritorial discussion. Proposals which were well advanced for establishing West African agricultural and veterinary research organizations have, I understand, been dropped for the time being.

One other matter that applies to all intertropical Africa is what we are likely to receive from our American friends under what is generally known as ECA assistance. Up to now there has been rather more talk than action on this, but the intention is clear—to bring to bear on African problems the particular skills and knowledge of the USA. Since the days of ECA are numbered—it ends in 1952—and the time taken to arrange each case is considerable—there has been some feeling that ECA assistance to Africa might not be very large; now, however, the principle of assistance from the USA will go on under the Point IV Program, which will run for at least three years from 1951.

The pattern of the scientific organization in each of the nine regions shows some similarity, particularly in the growth during recent years of regional research organizations with different degrees of autonomy, but integrated with the departmental system of executive government. The tendency will be for this regional organization of research to grow further and, although they may maintain their European contacts, the regional institutes will be the first places to turn for information on any African scientific matters.

One difficulty about the systems I have described is that, although they are rightly based on the individual scientific workers in the various regions, there is an inadequate system for the scientists in one region to consult with those in another unless individuals happen to be acquainted. The official system of communication between East Africa and the Congo, for example, is through the respective African governments to the colonial offices in London and Brussels which, by means of the foreign offices in the two capitals, can reach each other via ambassadors. Admittedly, there are short cuts to this process, but they will not provide that cooperation among scientists in different parts of Africa which the present stage of development demands. That is the main reason why the African Regional Scientific Conference of 1949 recommended the setting up of C.S.A. (Scientific Council for Africa South of the Sahara).

It is too early to say exactly what C.S.A. will do or how it will operate. The first thing is to get into close touch with scientists actually working all over the continent, and for that purpose we are getting together a panel of specialists in the various subjects and regions. We hope these men will function as consultants so that we can base our recommendations on those of active scientists who know the continent.

C.S.A. will operate from within Africa, but the major decisions will be taken for a long time to come by the metropolitan governments, most of which are in Europe. Hence another international body has recently been established—C.C.T.A. (Commission for Technical Co-operation in Africa South of the Sahara). It may seem muddling that there should be two independent bodies, both dealing with the international side of African science; but this is clear if one remembers that C.S.A. is composed of scientists operating within Africa, and with advisory not executive powers, and that C.C.T.A. is a body of administrators operating in Europe, and with executive powers. C.C.T.A. has already done a number of things; it has organized a series of international scientific conferences: on tsetse and trypanosomiasis at Brazzaville, on rinderpest at Nairobi, on soils at Goma, and on nutrition at Dchang. As a result of these C.C.T.A. has set up three permanent bureaus for tsetse and trypanosomiasis at Leopoldville/Brazzaville, soils in Paris, and epizootic diseases at Muguga. C.C.T.A. is, in fact, a system for obtaining joint executive action by six independent governments responsible for Africa.

In the future, C.S.A., whose job it will be to know just what is going on in research and will keep its finger on the scientific pulse in Africa, so to speak, may be expected to advise C.C.T.A. on what needs doing in a number of directions. C.C.T.A., if it accepts the advice, can cause executive action. Thus, although the regional development of research must go on, the machinery now exists for bringing the scientific resources in all the nine scientific regions of Africa I have considered to bear on each other. It remains to be seen whether these interlocking machines can be made to work.

I should like to finish on a personal note, since on and off I have been privileged to watch these things taking shape for a good many years. In the late 1920s I was doing personal research in Africa. There were few scientists then, and not much was done for them. If one wanted to do a job of research, one had to improvise more or less everything, grub up the funds from wherever one could, and live mostly under canvas. In the middle 1930s I attempted to survey the whole field of science in Africa. Conditions were beginning to improve, but nearly all science was on a territorial and an isolated and insular basis. In the 1940s we have seen the development of many regional organizations all over the continent, especially designed to enable research men to do good work. Now, in the 1950s we are beginning to see not only the territorial boundaries but the regional boundaries of science breaking down, as inter-African cooperation takes shape. By the 1960s we may see African science taking its full and proper place in the development of the continent.

Fact and Fiction in Criminology

ARTHUR L. BEELEY

Dr. Beeley, a social psychologist (Ph.D., Chicago, 1925), was born in England and educated there and in the United States. While on the faculty of the University of Chicago, he was also a research associate to the late Herman M. Adler, Illinois state criminologist. He has done extensive research in crime and punishment, both in this country and in England. He is the author of The Bail System in Chicago, Social Planning in Crime Control, *etc., and a frequent contributor to this and other scientific journals. He is a member of the American Sociological Society and fellow of the American Orthopsychiatric Association. He is at present head of the Department of Sociology and dean of the Graduate School of Social Work, University of Utah.*

TWO social problems transcend all others in importance: war and crime. War, of course, is fundamentally an international question, whereas crime is the perennial problem of our national economy. Both, however, have the same common denominator: they reveal the inherent difficulty human beings encounter in trying to live together in peace and security. Notwithstanding the great advances we have made in all other phases of our domestic life, we are notoriously ineffective in this area. What we hope for, but lamentably fail to achieve, is a society wherein life and property are held sacred and inviolable.

One of the greatest obstacles to the effective control of crime in America is the stock of antiquated ideas and divergent views held by the public. On few other subjects do the opinions and beliefs, even of well-educated people, differ so widely. It would be well-nigh impossible, nowadays, to interest a group of people in a general discussion of, let us say, the cause and cure of smallpox or malaria; yet it is always easy to start an argument over the merits of capital punishment or the validity of the parole system.

The patterns of crime and criminality are virtually unlimited; they therefore elude any tidy classification. In order to give point to my thesis, however, I have selected, at random, half a dozen types that have received wide publicity during recent months.

Some months ago, in New Jersey, a young veteran machine-gunned five members of his estranged wife's family, also wounding his wife and three others. Quite apart from our unwise policy of permitting the indiscriminate use of firearms by the civil population, why should murder be much more prevalent in this country than in any other Western democracy? The rate is ten times higher in this country than in Great Britain, for instance.

Consider, also, the case of a nineteen-year-old civil servant of Lansing, Michigan, who some time ago set fire to a five-million-dollar state office building. When this young man, father of a seven-month-old child confessed, he fatuously said, "I didn't think it would be a big fire. I figured I would get probation, so I wouldn't be called into the Army. I didn't want to leave my wife and baby." Do we know enough about the mentality, particularly the fears and the emotional immaturity, which, undoubtedly, lie at the foundation of such behavior?

The sex fiend, for example, is always a serious menace. Some time ago, also in New Jersey, a twenty-seven-year-old kidnapper and sex offender, formerly convicted as a habitual criminal, committed suicide to avoid capture by an armed posse. He is alleged to have kidnapped a young woman and later forced her fiance to witness the rape of his sweetheart.

Why is this particular type of crime apparently more frequent in the United States than in any other civilized country? Are we, as a nation, more preoccupied with sex than any other people? Do we have a larger proportion of potential sex offenders in the male population? Or is our machinery for the control and prevention of this type of crime ineffective?

San Francisco has an unenviable record in a bizarre type of crime—criminal abortion; so much so, that the San Francisco *Chronicle* recently reported that a certain chiropractor had been under suspicion for twenty-three years, and al-

leged that during this period he had performed some 8,000 illegal operations, grossing an estimated $100,000 a year. Most American cities, of course, suffer from some form of this criminal malpractice. What is the responsibility, not only of the medical profession itself, but of an enlightened civic community to punish and prevent such crimes?

Only a few months ago a woman physician was convicted of kidnapping the daughter of a rich contractor in New Mexico. It could hardly be argued, in this case, that such a crime springs from a dull intelligence. The more likely possibilities lie on the side of the lack of proper emotional development and, possibly, the personality disintegration of such an offender.

One is reminded, also, of the famous Loeb-Leopold kidnapping case, which occurred in Illinois some twenty-five years ago. It was my responsibility to observe and report the trial of this famous pair of murderers. This, it will be remembered, was the case of two brilliant young men, from wealthy families, who perpetrated what they thought would be "the world's greatest crime." Incidentally, history was made in this case by the psychiatric examination of the criminals by a number of eminent psychiatrists. Although the alienists did not find the boys insane, they nevertheless uncovered a long history of personality distortion in early life. Richard Loeb was later murdered in prison, in a homosexual affray. Nathan Leopold is now petitioning the Illinois Parole Board for release, on the grounds that during World War II he served as a guinea pig for a number of Chicago scientists who were experimenting with a substitute drug for quinine in the treatment of malaria. Should he be paroled?

Much more sinister than the individual crimes, of which the foregoing are but a few samples, selected at random, is organized crime in the United States, wherein we see the unsavory liaison between the racketeer and the politician. Thanks to the Kefauver Committee, we have recently witnessed a revelation as to the nature and extent of this type of syndicated racket. The case of Mickey Cohen in Los Angeles is typical, as is also the dramatic exposé of New York's Frank Costello, whose ill-gotten gains have been converted into a "respectable" business. Costello is apparently a disciple of Lucky Luciano, another gangster-racketeer, who was deported some time ago to his native Italy.

The proneness of human nature to theft, at any one time, and in a given culture, is often revealed in subtle, sometimes brazen forms. Witness the inroads of the professional gambler in intercollegiate athletics and the plethora of recent dismissals from the Bureau of Internal Revenue. One could multiply examples *ad infinitum.*

Two basic questions regarding crime and criminals have never been satisfactorily answered. The first is, that since criminals are *made* rather than *born,* what is it that attracts or leads them into crime? The second is, what is wrong with our machinery of prevention and punishment? The stupendous economic cost of crime, serious as it is, is by no means the greatest cost. Taken together, the loss of life and property, the suffering, the shame, and the general frustration of our social purposes, constitute by far the major loss to society.

Let us now look, for a few moments, below the surface of what, after all, are merely symptoms. First, let us see what the criminologists can tell us. At the outset, let me define the genus "criminologist," of which there are many subspecies. They seem to fall into two main categories: administrative and scientific.

On the administrative side there are, of course, the police and the detectives. Their accomplishments are exemplified by the brilliant work of our own FBI, on the national level; and by the outstanding work of such distinguished pioneers as August Vollmer, whose work at Berkeley is well known in this country and abroad. In England, of course, we think of Scotland Yard.

Another subspecies of the genus criminologist is the public prosecutor, of whom the most famous in America, perhaps, is Governor Thomas E. Dewey. Still another is the penologist, of whom the best-known examples in this country are Lewis E. Lawes, late warden of Sing Sing prison, and Sanford Bates, who for many years was director of the Federal Bureau of Prisons, and is currently Commissioner of Institutions and Agencies for the State of New Jersey.

On the scientific side, the criminologists fall into two categories: medical and sociological. The pioneer in the application of psychiatry to crime is William Healey, a neuropsychiatrist of Boston, whose lifelong studies on the nature and causes of juvenile delinquency are a paragon of excellence. He was succeeded in Chicago by the late Herman M. Adler, also a psychiatrist.

On the sociological side are such names as Burgess, of Chicago; Sellin, of Pennsylvania; Glueck, of Harvard; and Tappan, of New York University. These men have also been trained in social psychology, law, and psychiatry, and have made fundamental contributions to the new science of criminology.

Unlike the medical and the engineering sciences, the objective study of crime, criminals, and the administration of criminal justice is of very recent origin. In fact, there were no scientific studies in this field prior to about 1900. Not only is the science of criminology new, but a major difficulty faces the scientific worker because his findings are usually inaccessible to the average citizen. It would seem, therefore, that the knowledge of crime causation and the established principles of crime control ought to be stated briefly and accurately, without losing any of their scientific character, by those who have given many years of time and effort to their study.

Let us now analyze a few of the principal fictions that keep us from thinking clearly and, therefore, acting wisely in the matter of crime and its control.

1. *The fallacy that all crime is equally serious.* In the minds of many people the word "crime" has come to connote only serious crime, such as murder, kidnapping, robbery, etc., because of the fact that, in general, only such crimes are played up in the news. Consequently, when we speak of crime and criminality we unconsciously tend to think only of serious offenses.

The fact is that the great bulk of crime is petty crime, as is shown by the following percentages tabulated by me some years ago. They represent more than a million cases that came before the Municipal Court of Chicago during a ten-year period.

	Percentage
Quasi crimes (violations of city ordinances)	70.4
Misdemeanors	23.7
Felonies	5.9

These facts are so universally true that we can now say that the seriousness of an offense and the frequency of its occurrence tend to vary inversely. That is to say, the least serious offenses (e.g., drunkenness, disorderly conduct, etc.) are always the most frequent, whereas the most serious offenses (e.g., murder) are always the least frequent. This criminological law is amply confirmed by federal statistics.

2. *The fallacy that all prisoners are hardened offenders.* It is often taken for granted that a prison commitment is proof of hardened criminality. To say of a man, for instance, "He has served a sentence in jail," is to consign him permanently to the criminal class. This is unfortunate and confusing, especially when it is realized that, according to the U. S. Bureau of the Census, 46.9 per cent of the persons committed to American penal or reformatory institutions during the first six months of 1923 were sentenced for the nonpayment of fine. Moreover, the amount of the fine in 60.0 per cent of these cases was less than $20.00; in 23.0 per cent of the commitments, it was even less than $10.00. The census report rightly observes that persons imprisoned merely for the nonpayment of a fine are virtually punished for poverty.

Here, incidentally, is an administrative problem of some importance. Great Britain solved it twenty years ago by allowing convicted persons seven days for the payment of a fine or permitting the payment to be made on installments. This common-sense solution, together with the extended use of probation for first offenders, has greatly reduced the prison population of England.

3. *The fallacy that the criminal is a distinct physical type.* The prevalence of this misconception is due to the well-known work of Lombroso, an Italian physician, who, following his examination of the skull of a notorious brigand, concluded that all criminals are "atavistic" beings, persons who reproduce "the ferocious instincts of primitive humanity and the inferior animals." This theory gained wide popularity in the late nineteenth century and is responsible for the still-prevalent view that criminals are "hard-boiled," gorilla-like creatures.

In order to submit the Lombrosian theory to a test, an English criminologist, Goring, made elaborate studies of British convicts, comparing their head and body measurements with those of students, soldiers, and insane persons. His data conclusively *dis*proved the existence of a physical criminal type.

Yet, twenty years after science has refuted this superstition, it is still possible to find peace officers literally taken off their guard when the bandit is a well-dressed, handsome youth rather than a "suspicious-looking" character with all the earmarks of the proverbial criminal.

4. *The fallacy that criminals, in general, are less intelligent than the average population.* In the early days of mental testing it was hastily concluded that criminals are feeble-minded. When, however, following World War I, it was possible to apply group-intelligence tests—standardized on upwards of a million soldiers—to a large number of convicts in American prisons, it became clear for the first time that adult prisoners show about the same distribution of intelligence as the rest of the adult male population.

5. *The fallacy that criminals are insane.* The reports that came from the psychopathic clinic of the Chicago Municipal Court some years ago popularized the view that most adult offenders are either mentally deficient or are victims of schizo-

phrenia. Exhaustive studies in the prisons of Illinois and elsewhere, however, fail to confirm this fiction. On the contrary, it now appears that the frequency of insanity among criminals is no greater than it is among noncriminals of the same age and sex.

6. *The fallacy that crime is an expression of "an abandoned and a malignant heart."* Perhaps the most universal fallacy is this one, which is implicit in our criminal law; a conception that imputes free will to all offenders, except children, idiots, imbeciles, and lunatics. This theory is a carry-over from medieval philosophy and the common law of England. It is refuted, however, by an ever-increasing mass of evidence from the behavior sciences regarding individual differences in physical and mental capacity and, therefore, of moral responsibility.

7. *The habitual sex offender.* During the past two years, the American public has been incensed by the number and viciousness of sex crimes, especially upon little children. A wave of hysteria swept the country, special committees were appointed by various state governors, and even legislatures were convened to deal with this growing menace. The most intelligent action taken by any of the 48 states was that taken in New Jersey when Governor Driscoll recommended to the legislature the appointment of a commission on the habitual sex offender and provided $10,000 for its study and investigation.

In my opinion, the report of this commission is the most intelligent guide to the problem that has yet appeared. Among other things, the commission isolated a number of misconceptions held by the public regarding the sex offender. A few of these cherished beliefs include: (1) The popular fear that there are tens of thousands of homicidal sex fiends in the land, whereas it appears that most sex deviates are minor offenders, most of whom never come to official attention. (2) That the sex offender is usually a repeater. Careful studies of large samples of sex criminals show clearly that most of them get into trouble only once, and of those who do repeat, the majority commit some crime other than sex. (3) The fiction that it is possible to predict the number of serious crimes committed by sex deviates. Reports from 75 prominent psychiatrists say that it is impossible to predict the occurrence of serious crime with any accuracy. (4) That sex psychopathy, or sex deviation, is a distinct clinical entity. Two thirds of the psychiatric authorities consulted in the New Jersey investigation reveal a wide disagreement even as to the meaning of the term itself. (5) That sex offenders are oversexed. It was found that most of the sex deviates who have been treated under the law are *under-* rather than oversexed. (6) Finally, there is the fallacy that the sex problem can be solved merely by passing a new law or increasing the penalties of existing laws.

8. *The fallacy of a single cause.* One of the most widespread of all fictions regarding crime and criminals is the belief that there is one single cause. This fallacy has been refuted again and again, not only by the psychiatrists, but by the social psychologists as well. For instance, one of the most conclusive studies on this point was made by the psychologist Sir Cyril Burt, in London some years ago. He set out to discover the causes rather than to prove a contention. He compared a group of delinquent with a group of nondelinquent children and found four main factors to be paramount in more than 50 per cent of the delinquent cases: mental dullness, temperamental instability, disorganized family life, and friendships formed outside the home. The range of conditions that he found associated with delinquency, however, was not peculiar to delinquent cases. In the delinquent group there were nine or ten subversive factors associated with each case, and in a typical nondelinquent case, only three. His conclusion is therefore significant. "As a rule," he said, "it is either the number of factors or the combination of them that renders delinquency a probable result. On an average, therefore, each delinquent child is the product of nine or ten subversive circumstances, one as a rule preponderating, and all conspiring to draw him into crime."

These findings, and those of many others who have studied the matter scientifically, have been repeatedly confirmed. It is now incontestably clear that the causes of crime are plural rather than singular; that crime or delinquency (stating the matter more precisely) is the uniform consequence of many different antecedents. As a matter of fact, the terms "crime" and "delinquency" are generic ones, comparable to the words "sickness" and "disease" in the field of medicine; they apply to an equally large group of widely different entities.

The most far-reaching implication of our new knowledge of crime causation is that we can no longer hope to find a universal panacea or palliative. Crime and delinquency cannot be dealt with intelligently en masse any more than disease can be effectively treated or wholly prevented en masse. Progress in the treatment and prevention of crime will probably be achieved in much the same way it was achieved in the field of medicine and public health—namely, by the isolation and control of specific diseases or symptom complexes.

Such conclusions as these will be disappointing to many, especially the single-cause reformer. Yet, unromantic as they are, they nevertheless constitute the most solid ground yet discovered for a genuine science of criminology and its practical applications.

9. *The fallacy of local control.* Another fiction to which the American public tenaciously clings is the historical, but dubious, theory of local responsibility for crime control. Under our system, the federal government, of course, is merely one of delegated powers, so that the constitutional power to control and prevent crime has been retained by the states, except, of course, for interstate crime and offenses against the federal government. Local crime control (i.e., by municipalities and counties) is notoriously futile and inefficient. The local machinery of crime control is ineffective in two ways: first, because of the archaic nature of the criminal law (not so much, perhaps, the substantive law, as what may be called the adjective law), and, second, because of uncoordinated responsibility for law enforcement. In Los Angeles County, for example, there are 46 separate law enforcement agencies.

Some years ago the state of Michigan amended its constitution to provide a unified jurisdiction and a recorder's court for Detroit and Wayne County. The result of this simple innovation has been to greatly improve the administration of criminal justice in that metropolitan area. It is incredible that no other state, so far as I know, has followed suit.

A propos the point of obsolete and overlapping jurisdictions, one recalls the period in Chicago when Al Capone was at the height of his power and sinister influence. Whenever he came into court, he was flanked on one side by a lawyer of dubious ethics and on the other by a professional bondsman of even shadier character. The former would usually succeed in getting the court to postpone the trial as far as possible into the future. The latter was always able to furnish a bail bond, no matter how large the sum fixed by the court. In the interim, Capone and his gang would "bump off" certain of the state's witnesses, so that, as time went on, it was virtually impossible to bring Capone to trial. In fact, he was never convicted or imprisoned under the laws of Illinois, but finally served a sentence in a federal prison following a conviction for falsifying his income tax return.

The underlying difficulty in such matters is the organic law of our sovereign states, which, through the Bill of Rights, protects the accused person in unbelievable ways; it provides constitutional guarantees which were never intended to protect the gangster in a modern American city, but were, in fact, the historical basis of the English Bill of Rights of 1688, which was a bulwark of protection against the tyranny of the Stuart kings.

10. *Popular fallacies regarding punishment.* One of the most widespread misbeliefs is the notion that the deterrent effect of punishment varies directly with its severity. Consider any penal code and observe that the more serious crimes carry the greater penalties. This assumption, incidentally, is explicit in the so-called Baume's laws first introduced in New York state, under which a habitual offender, following his third conviction for felony, is automatically committed to prison for the rest of his life, it being assumed that his repeated offenses are proof, per se, of his incorrigibility. Why, by the same logic, are not his subsequent crimes proof, per se, of the ineffectiveness of his earlier punishments?

The sole justification for punishment is deterrence; yet many of our archaic practices are a carry-over from a prescientific age when expiation, retribution, and vengeance were the guiding principles in the treatment of offenders. It is now a penological axiom that the deterrent effect of punishment arises, not alone from its severity, but also from three other equally important factors—speed, certainty, and justice. In America, we have notoriously failed to achieve at least two of these objectives in the administration of criminal justice.

Our systems of punishment in this country are essentially historical. They range from lynching, the death penalty, flogging, imprisonment, and the fine to social supervision in a free society—i.e., probation and parole. All of them, with the exception of lynching and flogging, have some merit and should be administered according to the needs of the offender.

It is a well-established principle of penology that punishment should be individualized. The most advanced thinking on this point suggests that, following conviction in a criminal court, all offenders, irrespective of the offense, should be committed to a state board of corrections, where, after scientific diagnosis by a board of experts, a penological prescription would be written, and its recommendations carried out.

Imprisonment has been the backbone of the American prison system until recently. In 1931, however, the National Commission on Law Observance and Enforcement, appointed by President Hoover, reported that "The most important step we have taken in the individualization and treat-

ment of the offender is probation. No man," said the Wickersham report, "should be sent to a penal institution until it is definitely determined that he is not a fit subject for probation."

About the same time, the New York state legislature created a commission to investigate prison administration. They found that the general population of the state during the preceding decade had increased 21 per cent, but that the prison population had increased 75 per cent. "We must look for an extension of the probation system," said the New York State Commission, "if for no other reason than the fact that the mounting cost of the construction of penal institutions and the confinement of inmates therein must eventually become prohibitive."

In 1945, according to recent statistics, it appears that in New York state 74 per cent, or three out of every four persons convicted in the courts of New York state, serve their sentences on probation. This undoubtedly is a concession to two considerations: first, the prohibitive cost of maintaining prisons for so large a number of offenders; and second—and this is very important—that probation is now regarded as a satisfactory alternative to imprisonment.

Most offenders are first offenders. Studies of probation show, convincingly, that the great majority succeed under probation. It should be added that incarceration in an American prison costs approximately ten times the annual cost of supervision on probation.

Let me conclude this brief analysis of an obviously complex problem by making the following summary statements.

It is my conviction, after much study of the subject in this country and Great Britain, that our colossal failure to control and prevent crime in America is due in large part to three closely interrelated causes:

First. Most American communities are, in fact, engaged in a futile attempt to control crime by means of a fortuitous set of out-moded arrangements better suited to a rural America of a century ago than to the urban complexities of today's industrial society. Specifically, we are attempting to cope with the twentieth century patterns of criminality by means of obsolete, overlapping, uncoordinated facilities for the enforcement, prosecution, and punishment of wrongdoers, on the local level. The new technology of transportation and communication, for instance, has completely revolutionized all our social relations, and it is axiomatic that crime always increases in times of rapid social change. The situation therefore calls for a complete overhaul of our machinery for the administration of criminal justice on all levels of government—local, state, and national.

It is readily admitted, of course, that certain inherent difficulties make it harder to protect life and property in America than in almost any other free society: differences in geography; the varied ethnic background of our people; the popular impatience with restraint; and the greater mobility of Americans and consequent anonymity. These are only a few of the limitations under which we must operate.

The *second* factor has to do with personnel and stems from the first. It seems equally futile and, one might add, somewhat unfair, to hold local law enforcement officers solely responsible for crime control and prevention. In addition to their limited powers, these men are generally untrained, poorly paid, politically appointed (or elected), and sometimes corrupt. Moreover, they are often held in contempt by a severely critical public.

The *third* factor is a logical corollary of the first two. The American public is extremely illiterate regarding the true nature and causes of crime and the wisest schemes of punishment and prevention, as evidenced by the prevailing wide range of popular fallacies. Our lawmakers, too, are equally confused.

John Q. Public is generally frustrated, first, by reason of his daily diet of horrifying crime news, reported and sometimes exploited by the press; second, by the inability of his elected representatives to work out an effective system of crime control and prevention.

Great credit is due Senator Estes Kefauver and his Special Committee to Investigate Organized Crime in Interstate Commerce. Its recommendations, especially those proposing the creation of a permanent crime commission for each state and a similar body for the federal government, public agencies charged to make a continuous survey of the crime problem, are sound and statesmanlike proposals.

One cannot, however, agree with the committee's melodramatic technique of publicity by television. Even granted that a criminal investigation may be regarded by some 20 million housewives as a form of entertainment, it is nevertheless not in the American tradition of "justice under law" to allow such an investigation to become what President Truman has rightly called "a Roman holiday." Furthermore, inquisition by television can become a form of "third degree," raised to the nth power.

What is needed is not so much publicity in the accepted meaning of that word, but rather a systematic program of adult education on the subject. For example, what a rare and magnificent opportunity lies at the door of the public schools, to plan a far-flung scheme of civic instruction and character education, dealing with the social origins and the tested wisdom of the moral sanctions that lie at the root of our free society. Someday, I predict, a brilliant high-school teacher will make a name for himself by the simple device of taking the penal code of his own state and relating it, imaginatively, to the prison population of that same state, using actual life histories as study materials in a civics course in crime prevention.

Crime in the United States is a blot on our escutcheon. It is not only our duty but, I am convinced, within our power to do something about it. The philosopher Alfred North Whitehead clearly defined responsibility in such circumstances, when he said, "Where attainable knowledge could have changed the issue, ignorance has the guilt of vice."

SMO ON THE AIR

Station	Sponsor	Time
	Sunday	
KLBM, La Grande, Ore.	Baker-Union Department of Health (Research Report)	10:15 A.M.
	Monday	
WOI-FM, Ames, Iowa	Iowa State College of Agriculture and Mechanic Arts (Articles of Interest)	7:45 P.M.
	Tuesday	
WEVD, New York City	Wendell W. Rázim (Science for the People)	9:00 P.M.
	Wednesday	
CKPC, Brantford, Ont.	The Telephone City Broadcast Limited (Modern Science)	9:45 P.M.
	(Irregular)	
KBKR, Baker, Ore.	Baker-Union Department of Health (Research Report)	....

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SCIENCE ON THE MARCH

THE METALLURGY OF THE LESS FAMILIAR ELEMENTS*

THE borderline between common metals and those that are rather vaguely termed the less familiar metals is constantly changing. An uncommon metal today may be commonplace tomorrow. A familiar example is the way aluminum and magnesium, which were on the dark side of the border not many years ago, have moved over to places of major commercial importance. Titanium and zirconium are preparing to step over soon. Many metals are looming in the background as contenders for the position of the currently most important new useful metals of the future.

Of the 98 elements reported so far, about four fifths are metals. Of these hardly more than a dozen are really common; hence there is a substantial reserve of metals on which to draw for those unique properties that scientific advances are always demanding. It is obviously impractical to cover the metallurgy of all these in one short discussion. Instead, major attention will be given to the general methods being developed for obtaining the pure metals, to metal coatings over base metals, and to a few of the most interesting and potentially important of the unusual metals. Emphasis is thus given to chemical metallurgy rather that to the equally fascinating developments in physical metallurgy.

There are three main considerations in determining the probable usefulness of a metal: availability, ease of extraction, and properties. Modern civilization demands vast quantities of metallic products, and, unless the earth can supply the metal in substantial amount, its use is handicapped, regardless of the excellent properties it may possess. The platinum group, for example, would be a wonderful addition to our list of structural materials if they could only be regarded in terms of available tons in place of ounces. The difficulty of metal recovery, which strongly influences cost and large-scale production, plays an important, though frequently a temporary, role. This is the challenge to the metallurgist. Sometimes the true properties are not uncovered because the metal has never been made in a sufficiently pure form. Extraction problems, then, may temporarily obscure an abundant and desirable metal, as it has done with titanium, whereas a metal with poorer over-all properties but one which is easily reduced, such as zinc, or tin, or mercury, has been used for many centuries. Properties, of course, form the greatest consideration. Thus the valuable properties of uranium and radium overbalance their scarcity and difficulty in extraction, whereas sodium and silicon, which are in overwhelming abundance and recoverable at low cost, find a greatly disproportionate field of usefulness.

Table 1 is a tabulation of most of the metals in order of their abundance in the first 10 miles of the earth's crust. These are fairly well-known data rearranged to show an abundance comparison, with aluminum as 100. Fortunately, minerals of even very scarce metals are frequently concentrated and rather easily found; hence, there is not necessarily a direct quantitative relationship between the immediate availability of a metal and its position in this tabulation. This does give a fair idea, however, of the fundamental availability of the metals in the future.

Examples of the influence of ease of reduction of metals from their ores on their adoption as common metals are given in Table 2. Some of our oldest metals (copper, tin, gold, silver, and lead) did not necessarily occur in abundance, but ease of reduction gave them a preferred position among early useful metals. Iron, in great abundance, but still comparatively easy to reduce, soon assumed the emperor's position, which it still holds. More recently, the abundant, but difficult to extract metals, such as aluminum, magnesium, and titanium, are moving into a role of increasing importance. This trend is continuing at a constantly accelerated pace as new materials, techniques, and needs catalyze the rate of research and development.

Some Types of Extractive Metallurgy Processes

The normal carbon reduction of metal oxides, so effectively used on a large scale in the blast-furnace smelting of iron, lead, and antimony, or in the reverberatory smelting of copper and tin, finds only limited application in reduction of the scarcer, more refractory, and less well-known metals. This also holds for carbon reduction accompanied by volatilization and condensation of the reduced metals, long used in zinc metallurgy. How-

*Based on a paper presented December 29, 1950, at the Inorganic Chemistry Symposium, Section C, American Association for the Advancement of Science, Cleveland, Ohio.

TABLE 1

RELATIVE ABUNDANCE OF METALS IN THE EARTH'S CRUST*

(Aluminum Taken as 100)

Silicon	313	Sodium	32
Aluminum	100	Potassium	29
Iron	58	Magnesium	24
Calcium	41	Titanium	7
(Range of 1.0–0.1%)			
Manganese	1.06	Zirconium	0.22
Strontium	.48	Rare earths	.14
Nickel	.11	Nickel	.11
Rubidium	.35	Copper	.11
Chromium	0.23	Vanadium	0.11
(Range of 0.10–0.01%)			
Tungsten	0.08	Lead	0.02
Lithium	.07	Molybdenum	.02
Tin	.05	Niobium (Cb)	.02
Zinc	.05	Tantalum	.02†
Cobalt	.05	Gallium	.02
Yttrium	0.04	Thorium	0.01
(Range of 1–8 lbs/100,000 lbs Aluminum)			
Germanium	0.008	Uranium	0.005
Cesium	.008	Hafnium	.004
Beryllium	.007	Boron	.003
Arsenic	.006	Antimony	0.001
Scandium	0.006		
(Range of 1–7 lbs/1,000,000 lbs Aluminum)			
Selenium	0.0007	Bismuth	0.0002
Cadium	.0006	Tellurium	.0001†
Mercury	.0006	Indium	.0001
Thallium	0.0003	Silver	0.0001
(Really Rare Metals)			
Palladium	0.000011	Rhodium	0.000001
Gold	.000006	Rhenium	0.000001
Platinum	.000006	Osmium	1.0^{-7}
Iridium	0.000001	Radium	1.0^{-9}

Ruthenium, polonium, new elements———

* GOLDSCHMIDT. *J. Chem. Soc.*, Pt. 1, 655 (1937).

† Value not given by Goldschmidt, estimated from general position with associated elements in data by Clark and Washington (*Professional Paper No. 127*, USGS [1924]).

ever, the heating of metal oxides with carbon, accompanied by chlorination, or for the production of other halides, is a useful method for obtaining a volatile or soluble compound of many refractory metals, which then can be separated from other constituents and reduced. Thus magnesium chloride has been prepared in this way on a large scale for subsequent recovery of the metal by electrolysis; zirconium chloride is so produced and zirconium is also recovered by reduction with magnesium.

Electrolytic processes. One of the most effective methods for producing pure metals, of course, is by electrolysis. This has been used both for primary recovery and for refining of most of the common metals. Deposition from aqueous solutions also has been used effectively to produce indium, gallium, thallium, and cadmium. An interesting variation when using an aqueous electrolyte to recover a reactive metal is to use a mercury cathode and later recover the deposited metal by distillation of the mercury. This was demonstrated by Mme. Curie and co-workers some 40 years ago in producing metallic radium, and the same principle still finds applications now, as in exploring means for producing a metal powder.

Incidentally, using mercury as a convenient tool to gather those metals with which it amalgamates, and later removing the mercury by distillation, has a far greater field than in electrolysis. Also, mercury may be used conveniently as a carrier of a reactive metal, such as sodium, to effect reactions under controlled conditions. This field has been aptly referred to as "amalgam metallurgy."[1]

Some reactive metals have been successfully deposited from solution in nonaqueous electrolytes. Although not yet important commercially, the exploration of nonaqueous electrolytes in research has been producing interesting results, and this is definitely a field of metal recovery and plating that should not be overlooked. As examples, lithium can be deposited by electrolysis of lithium chloride in pyridine; heavy deposits of aluminum can be deposited from aluminum chloride and ethylbromide (or ethyl pyridinium bromide) in toluene. Liquid ammonia has been used as an electrolyte to deposit experimentally beryllium, thallium, arsenic, and some of the precious and common metals.[2]

The most successful electrolytic method for recovery of reactive and refractory metals has been the use of a molten-salt electrolyte. This forms the basis for the very successful commercial production of aluminum, magnesium, sodium, and the other alkali and alkaline-earth metals (Li, K, Rb, Cs, Ca, Sr, and Ba). It is also a means for producing uranium, beryllium, thorium, cerium, and metals of the rare-earth group, including the impure mixture known commercially as misch metal. This procedure is particularly convenient when the electro-

TABLE 2

ABUNDANCE–EASE-OF-REDUCTION RELATION TO COMMON USE

Relatively Scarce, Easily Reduced	Abundant, Easily Reduced	Abundant, Difficult to Reduce
Copper	Iron	Aluminum
Lead		Magnesium
Tin (bronze)		Titanium
Zinc		
Mercury		

lyte is at such a temperature that the metal is deposited in the molten state so that it can be removed continuously.

Some of the high-melting metals can be reduced electrolytically from their molten salts, but instead of forming a molten pool or a coherent deposit they become distributed through the electrolyte as a crystalline metal powder. This is the case with tantalum and niobium (columbium). The electrolyte here is a double fluoride with potassium. Massive metal is obtained by dissolving the soluble salt away from the product, recovering and washing the powder in a tabling operation, and pressing and sintering the tantalum or columbium by powder metallurgy. There is reason to believe that some of the other high-melting metals, such as titanium and zirconium, can be reduced electrolytically in a molten-salt electrolyte also, but with a more difficult problem of recovering a nonmassive deposit in a sufficiently pure form to obtain a ductile metal.

Metal replacement. Trading one metal that is expendable to throw another metal out of solution is another well-known electrochemical procedure that is finding many new applications and a few variations. One of the oldest applications, cementation of copper on iron, as by adding shredded tin cans or other scrap to copper-containing mine waters, is a common sight to observant travelers in the copper-mining districts of the West. Zinc dust has been a particularly useful replacement metal, not only in the well-known precipitation of gold and silver from cyanide solutions, but in the removal of many metals from solution, as in purification of a zinc sulfate electrolyte prior to electrodeposition. Since indium, germanium, gallium, and cadmium are frequently associated with zinc ores, this replacement reaction may give these metals in sufficient concentration to warrant subsequent separation and recovery. This is true not only in recovery of by-products from an electrolytic zinc plant, but in the hydrometallurgical treatment of the baghouse and Cottrell dusts from a pyrometallurgical zinc plant.

More recently, metal replacement has been used in dry, high-temperature reactions. Many of these processes are variations of the thermite type of reaction, using aluminum, magnesium, silicon, or other alkali or alkaline-earth metal to break up a metal compound. Thus, work is in progress to obtain titanium by reacting purified calcium with titanium dioxide; thoria is reduced to thorium by calcium reduction in presence of calcium chloride; uranium can be reduced from its oxides by calcium, magnesium, or aluminothermically. Ductile vanadium has been prepared by calcium reduction of vanadium pentoxide.[3] Barium and strontium can be produced by oxide reduction with silicon or aluminum in a vacuum at 1150° C.[4] Silicon has been used recently with technical success in large-scale reduction of magnesium oxide to magnesium, which was volatilized and condensed to give the commercially pure metal. Such reactions take place in vacuum, or at least in an inert atmosphere. (Replacement reactions involving reduction of metal halides are discussed later.)

Another variation of metal replacement is to carry out the reaction in a molten-salt medium. Little work has been done in this field, and it forms a promising area for development. Metal coatings have been produced conveniently by replacement in a fused-salt bath. Tin alloys may be formed on copper, iron, and some other metals by immersion in a molten chloride-salt mixture containing stannous chloride; excellent chromium-iron diffusion coatings are formed on iron and steel articles by immersion in hot molten barium chloride containing chromous chloride as a constituent.[5] This has the advantage, under some conditions, of greater speed and ease of control than when using solid materials or a volatilized constituent.

Halide metallurgy. In producing many of the uncommon metals, it is easier to reduce their halides than their oxides. There are so many applications and ramifications to this general method of treatment that it justifiably can be called halide metallurgy to differentiate it from the older fields of normal pyrometallurgy and hydrometallurgy.

Dry replacement reactions, or reduction of a metal compound by a more active metal, in many instances works particularly well when the metal compound is a halide. The magnesium reduction of titanium chloride, or of zirconium chloride, is a good example. By passing either of these chlorides into a bath of molten magnesium, rapid reduction takes place exothermically, and, on completion, the resultant magnesium chloride and residual magnesium may be volatilized away to leave a metal sponge suitable for arc-melting to massive metal. Similarly, silicon of high purity has been prepared by reacting purified silicon tetrachloride with zinc vapor.[6] Calcium reduction of uranium fluoride is a preferred method of obtaining pure uranium.[7]

Hydrogen reduction of metal halides is assuming increased importance, particularly as materials of construction to resist the resultant hydrogen halide are improved. Cobalt, nickel, and iron powder can be produced by reduction of the solid chloride at a rather low temperature. Reduction of volatilized

halides by hydrogen has been of particular interest in producing metal coatings. Thus, many of the high-melting metals, tungsten, molybdenum, tantalum, and columbium, that are difficult to get in massive form are readily deposited by volatilizing one of their halides and reducing it on a heated metal surface with hydrogen. Production in Germany of titanium by hydrogen reduction of titanium tetrabromide has been described—as well as reduction of the tetrachloride with sodium and the oxide with calcium hydride.[8]

Fortunately, many of the halides decompose by pyrolysis alone. Titanium, zirconium, hafnium, thorium, vanadium, and chromium are among the metals which can be produced in a very pure massive form by thermal decomposition of their iodides. This can be done by passing the pure iodide into a previously evacuated chamber containing a heated surface, such as an electrically heated wire, or by using a bulb in which a crude metal charge is present, and iodine serves as a carrier between the charge and the heated surface.[9] This reaction is not limited to the iodide by any means, but, in many instances, the iodide decomposes at a lower temperature, and iodine can be more conveniently handled and recovered (as the liquid or solid) than the other halides. Molybdenum and tungsten are more readily obtained from their respective chlorides or bromides.

Another associated type of reaction which offers interesting possibilities is the formation of a volatile subhalide at an elevated temperature which disproportionates at a lower temperature. Thus, aluminum trichloride (or bromide or fluoride), when heated in the presence of metallic aluminum, and preferably under partial vacuum, forms a subchloride. This volatile compound disproportionates on cooling into aluminum and the trichloride. The reaction consequently has possibilities in refining or recovering high-purity aluminum from a low-grade crude metal.[10] Similarly, as familiarity grows with the high-temperature properties of compounds of the less familiar metals, other examples may be found where this will become a useful metallurgical procedure.

Metal Coatings

Closely associated with the recovery of pure metals from their ores is the deposition of metals as coatings on another metal base. This is particularly important with the unusual metals, to secure a desired surface at less cost, or for protection against oxidation or corrosion. Some of the techniques and reactions common to both coating and metal-recovery work can be best described under coatings. However, coatings applied electrolytically are considered to be outside the scope of this discussion.

Decomposition from volatilized halides. Coating by pyrolysis of a volatilized metal compound (usually a halide) is not common, but it has been well demonstrated in the laboratory. Uranium, thorium, vanadium, titanium, zirconium, and hafnium may be deposited by thermal dissociation of their respective iodides either in an inert atmosphere or at low pressure. The temperature required for decomposition is usually in the range of 800°–1800° C, and the choice of base metal to secure a pure metal coating is limited, but coatings sometimes can be applied by this method when other methods fail. Rhenium can be plated similarly by decomposition of the volatilized chloride.

Hydrogen reduction is more readily applied to the decomposition of many volatilized metal halides. A somewhat lower temperature and atmospheric pressure can be maintained. This is the preferred way to coat various metals with tantalum, niobium (columbium), molybdenum, tungsten, boron, and silicon. With reactive base metals, diffusion of the coating takes place into the metal base, and replacement may occur as well as some reduction by the hydrogen atmosphere. In siliconizing steel by passing silicon tetrachloride over a heated steel object, for example, a coating can be formed entirely by replacement of iron or, with a high concentration of hydrogen in the atmosphere, part of the silicon may be deposited by reduction and part by replacement.

Because of the need for materials to resist very high temperatures, there has been a growing need for refractory coatings to protect high-melting metals which have the mechanical properties desired but not the oxidation or corrosion resistance. Vapor-deposition methods form a particularly useful field for securing stable and unusual coatings. Aside from applying metals by this means, carbides, borides, silicides, nitrides, and even oxide coatings or mixtures have been so applied. By mixing volatilized metal compounds, two or more metals can be codeposited under proper conditions; many carbides can be deposited by using a hydrocarbon gas along with the hydrogen atmosphere. Thus, this general means of coating is a powerful, versatile tool that is expected to have many practical applications in the future. The various reactions and a survey of the methods used to form refractory coatings by vapor deposition have been covered in recent publications.[11, 12]

As an example of refractory-coating development, by siliconizing molybdenum (passing silicon

tetrachloride gas in hydrogen over molybdenum) a remarkably oxidation-resistant coating can be formed which will withstand temperatures up to 1700° C for many hundreds of hours.[13] Even higher temperatures and longer times for useful operation appear to be possible. A corollary to such work is the casting of the molten coating material to give a solid body, or forming such a refractory molybdenum-silicon base body by powder metallurgy.

Miscellaneous methods. The use of a molten salt bath as a medium to effect metal coating by replacement has been mentioned previously. In chromizing steel by either gaseous or molten-salt replacement, it is possible to secure impervious, corrosion-resistant coatings, or, by dissolving out the steel core, to make tubes and other hollow metal objects.

Thermal decomposition of a metal carbonyl gas has been used for many years in refining nickel, and more recently in making a high-grade iron powder. Considerable laboratory work has been done on depositing some of the less common metals from their volatilized carbonyls—particularly tungsten and molybdenum.[14] The platinum-group metals may be deposited by thermal decomposition of their carbonyl halides, and platinum has been deposited from certain other organometallic compounds, such as the acetyl acetonate. However, such deposition is still at the laboratory curiosity stage. In considering ways to recover a pure metal, as well as to coat with it, carbonyl formation is a factor worth noting.

Vacuum evaporation and cathode sputtering are coating methods applicable so far only in making very thin coatings. It is possible with some of the more volatile metals to literally vapor-coat, as with antimony, arsenic, and zinc, by reaction of the metal vapor with a base metal. The low-melting metals frequently can be used in hot-dipping baths.

Metal spraying has advanced to the point where a surprisingly large number of metals can be sprayed onto a nonmetallic as well as a metallic surface. This includes high-melting metals such as molybdenum, tantalum, and even tungsten. An interesting innovation has been the use of a plastic into which a metal powder can be incorporated and the mixture extruded to form a wire for use in a metal-spraying gun. This is useful in applying a nonductile metal.

Hydrogen Reduction, Hydrides, and Vacuum Metallurgy

Although hydrogen reduction of metal compounds has been partially covered in discussing methods of metal recovery, the growing importance of hydrogen as a reducing agent in commercial metallurgy deserves special mention. Not long ago, the explosion hazards in handling hydrogen were considered to be such that serious consideration would scarcely be given a method that involved its use. It is still regarded with suspicion by metallurgical plant managers. However, advantages in its use for many applications are such that a metallurgical process involving hydrogen is given attention, at least. In the metallurgy of many of the unusual metals, hydrogen is practically indispensable.

Tungsten is produced by hydrogen reduction of tungstic oxide; molybdenum is likewise produced from molybdic oxide. Rhenium is most conveniently prepared as the metal powder by reduction of potassium perrhenate at about 1000° C in hydrogen. There are many other examples.

A convenient way to effect reduction of some unusual metal compounds is to use the hydride of a reactive metal, whereby a combination of replacement, active-hydrogen reduction, and a protective hydrogen atmosphere may be attained. The production of calcium, sodium, lithium, and other metal hydrides has become a thriving commercial enterprise.[15] Calcium hydride, used during World War II as a convenient source of hydrogen for balloons, is perhaps the most important for reducing various refractory oxides, including titanium and zirconium oxides. Usually this first gives a hydride of the metal being reduced, but it is readily converted to the metal by heating. Some of these hydrides form a useful pure-hydrogen "sponge" by absorbing hydrogen at one temperature and releasing it on heating more strongly.

Many of the hydrides of the unusual metals (as of germanium, indium, gallium, thallium, arsenic, selenium, and tellurium) are volatile. These can be reduced thermally. This procedure sometimes forms a very convenient way of selective plating or of deposition on glass or other nonmetallic objects.

The commercial use of vacuum technology has increased along with the increased use of hydrogen and of inert atmospheres to handle the most reactive of the unusual metals. Some metals, like titanium and zirconium, react with practically everything but the inert gases, and vacuum or an atmosphere of helium or argon is needed in preparing equipment for the reduction operations and in melting or oxide-free annealing. Here again, so many metallurgical applications have been found that the term "vacuum metallurgy" has been effectively used.[16] Fortunately, the wartime development of vacuum-pump technology and the large-scale application of vacuum in magnesium and ura-

nium production acquainted metallurgists with vacuum as a practical commercial operation.

Unusual metals are in increasing demand to fill industrial and military needs. Progress has been rapid recently in recovering the pure metals, which frequently give an entirely new field of usefulness because of improved properties not realized from the impure metal known in the past. This trend toward making purer metals to give improved properties and to widen alloying possibilities is certain to continue. This should result in increased usefulness of such metals as vanadium and chromium, as well as titanium and zirconium, which are already well started as commercial ductile metals.

The needs ahead are great. Many of the unusual metals have a potential physical metallurgy that is as complicated as that of copper and aluminum, and possibly of steel. Many of the present means for extraction of the pure metals are unsatisfactory and expensive. Consequently, with all regard to the rapid progress that has been made in applying new techniques to the recovery and use of these metals, only a small beginning has been made in their potential exploitation.

BRUCE W. GONSER

Battelle Memorial Institute
Columbus, Ohio

References

1. HOLM, H. *Research*, **3**, 407 (Sept. 1950).
2. BOOTH, H. S. and MERLUB-SOBEL, M. *J. Phys. Chem.*, **35**, 3303 (1931).
3. MCKECHNIE, R. K., and SEYBOLT, A. U. *J. Electrochem. Soc.*, **97**, 311 (1950).
4. KROLL, W. J. *Mining and Met.*, **27**, 262 (May 1946).
5. CAMPBELL, I. E., *et al. J. Electrochem. Soc.*, **96**, 262 (1949).
6. LYON, D. W., OLSON, C. M., and LEWIS, E. D. *Trans. Electrochem. Soc.*, **96**, 359 (1949).
7. CHIPMAN, J. *Metallurgy in the Development of Atomic Power.* Tech. Inf. Div., Oak Ridge Directed Operations. (Declassified Nov. 25, 1946.)
8. BIOS report. *Metal Ind.*, **70**, 363 (1947).
9. CAMPBELL, I. E., *et al. J. Electrochem. Soc.*, **93**, 271 (1948).
10. GROSS, P. *In Refining of Nonferrous Metals.* London: Inst. Mining and Metallurgy, 461 (1950).
11. POWELL, C. F., CAMPBELL, I. E., and GONSER, B. W. *The Formation of Refractory Coatings by Vapor-Deposition Methods, R-137.* Rand Corporation (Mar. 25, 1949).
12. CAMPBELL, I. E., *et al. J. Electrochem Soc.*, **96**, 318 (Nov. 1949).
13. BEIDLER, E. A., *et al. Ibid.*, **98**, 21 (1951).
14. LANDER, J. J., and GERMER, L. H. *Trans. Am. Inst. Mining Met. Engrs.* **175**, 648 (1948).
15. GIBB, T. R. P., JR. *J. Electrochem. Soc.*, **93**, 198 (1948).
16. SCHLECHTEN, A. W. *Eng. Mining J.*, **71**, 151 (July 1950).

New Books Received

Statistical Methodology Reviews 1941–1950. Oscar Krisen Buros, Ed. x + 457 pp. $7.00. Wiley, New York. 1951.

The Kernel Function and Conformal Mapping. Stefan Bergman. vii + 161 pp. Illus. $4.00. American Mathematical Society, New York. 1950.

The Calculus of Finite Differences. L. M. Milne-Thomson. xxiii + 558 pp. Illus. $4.50. Macmillan, New York. 1951.

Calculus and Analytic Geometry. George B. Thomas, Jr. 685 pp. Illus. $6.00. Addison-Wesley, Cambridge, Mass. 1951.

Air War and Emotional Stress. Irving L. Janis. ix + 280 pp. $5.00. McGraw-Hill, New York. 1951.

Gall Midges of Economic Importance. Vol. V: *Gall Midges of Trees.* H. F. Barnes, 270 pp. 15/–. Crosby Lockwood, London. 1951.

The Integument of Arthropods. A. Glenn Richards. xvi + 411 pp. Illus. $6.00. University of Minnesota Press, Minneapolis. 1951.

Intermediate Algebra. (2nd ed.) Raymond W. Brink. xi + 295 pp. Illus. $3.00. Appleton-Century-Crofts, New York. 1951.

Introduction to Number Theory. Trygve Nagell. 309 pp. $5.00. Wiley, New York. 1951.

The Classical Theory of Fields. L. Landau and E. Lifshitz. Trans. from the Russian by Morton Hamermesh. ix + 354 pp. Illus. $7.50. Addison-Wesley, Cambridge, Mass. 1951.

Ecology of Foraminifera, Northwest Gulf of Mexico. Part I: *Foraminifera Distribution.* Fred B. Phleger. Part II: *Foraminifera Species.* Fred B. Phleger and Frances L. Parker. 152 pp. (No price given.) Geol. Soc. Am., New York. 1951.

Arthritis and the Rheumatic Diseases. Philip Lewin. ix + 175 pp. $3.50. McGraw-Hill, New York. 1951.

Traité de Zoologie. Vol. X, Parts 1 and 2: *Insectes Supérieurs et Hémiptéroïdes.* Pierre-P. Grassé, Ed. 1,948 pp. Illus. 6,500 fr. Masson, Paris. 1951.

Statistische Methoden. (2nd ed.) Arthur Linder. 238 pp. Illus. 30.–, clothbound; 26.–, paperbound. Birkhäuser, Basel.

Finite Matrices. W. L. Ferrar. vi + 182 pp. Illus. $4.00. Oxford University Press, New York. 1951.

Dictionary of Mathematical Sciences. Vol. I, German-English. Leo Herland. 235 pp. $3.25. Frederick Ungar, New York. 1951.

Statistics for Medical Students. Frederick J. Moore, Frank B. Cramer, and Robert G. Knowles. viii + 113 pp. Illus. $3.25. Blakiston, Philadelphia. 1951.

An Introduction to Thermodynamics, the Kinetic Theory of Gases, and Statistical Mechanics. Francis Weston Sears. x + 348 pp. Illus. $6.00. Addison-Wesley, Cambridge, Mass. 1950.

Outline of Fundamental Pharmacology. David Fielding Marsh. xxxi + 219 pp. Illus. $6.00. Thomas, Springfield, Ill. 1951.

BOOK REVIEWS

THE NATIONAL NUCLEAR ENERGY SERIES

Preparation, Properties, and Technology of Fluorine and Organic Fluoro Compounds. Charles Slesser and Stewart R. Schram, Eds. 868 pp. $10.50. McGraw-Hill, New York. 1951.

THIS volume is one of a series which was organized to serve as a record of the research work done under the Manhattan Project and the Atomic Energy Commission. When completed, some 60 volumes will have been published in eight divisions, as follows: I, *Electromagnetic Separation Project*; II, *Gaseous Diffusion Project*; III, *Special Separations Project*; IV, *Plutonium Project*; V, *Los Alamos Project*; VI, *University of Rochester Project*; VII, *Materials Procurement Project*; VIII, *Manhattan Project*. These volumes are being released as rapidly as declassification will permit and represent a tremendous amount of work on the part of the editors in reducing duplication and discrepancies in factual data and conclusions that are the natural result of such a large research effort. The volume on fluorine compounds represents the only volume of Division VII that can be released at present.

As part of the production of atomic bombs, it was necessary to prepare resistant materials for handling UF_6 in the gaseous-diffusion separation process, and the materials selected were fluorinated hydrocarbons. This book contains the technical description of the work done on the development of industrial-scale production of fluorine compounds and represents the status of this work at the end of 1945. The early chapters describe the preparation and handling of fluorine on an industrial scale. This is followed by a detailed description of the research done on the partial fluorination of organic chloro compounds, an intermediate step in the process of producing fluorocarbons, and is completed with a discussion of the various methods of synthesizing highly fluorinated materials. In addition, the volume contains a brief account of the preparation of chlorotrifluoroethylene polymers and other areas related to the project. Two appendices, the first being a clarification of the different nomenclature systems used by the authors, and a good index complete the book.

This volume has been well planned by the editors and is excellently written, although widely varying styles of writing appear because of the large number of contributors involved. Since the material covered pertains principally to industrial practices and much of it has appeared elsewhere, the book is recommended to those who are primarily interested in the field of fluorine chemistry or who wish to include in their libraries chemical research of historical significance.

OGDEN R. PIERCE

Chemistry Department
Purdue University

LIFE IN THE CHESAPEAKE

The Bay. Gilbert Klingel. x + 278 pp. Illus. $4.00. Dodd, Mead, New York. 1951.

THIS unusually well-written book about the natural history of Chesapeake Bay is filled with many poignant passages of description. Nature's sounds, sights, and odors are experienced as the author takes the reader from one end of the bay to the other, from the plankton-teeming surface to the olive-colored bottom 50 feet below. Few naturalists have ever explored and recorded as intimately and as interestingly as Klingel has done in *The Bay*. The ways of birds, mammals, fishes, insects, and even the lowly jellyfish and protozoa are written about with great insight and feeling.

Mr. Klingel makes no pretense of presenting a scientific account, yet an amazing amount of scientific information is included in his tales of bay adventures. The bizarre life history of the jellyfish, the birth of a litter of muskrats, the death of an oyster, the nocturnal display of phosphorescence from the *Noctiluca* protozoan, and a host of other common but little appreciated phenomena are accurately and entertainingly treated.

The book might well have begun with the second chapter on "Life Begins in the Chesapeake," not that the first chapter fails in interest or lacks drama, but rather that it belongs with the later chapters on underwater explorations. It would appear that some malicious fairy, in the form of a publisher, wanted the book to begin with a "Beebe-ish" fling into the depths—and the Chesapeake, for all its underwater interest, is cold, dark and jellyfish-infested during night diving ventures. The second chapter, on the other hand, is warm, sunny and pleasant, and begins at the beginning with the genesis of water droplets in the fog, a fluffy, baby tern freshly cracked from its speckled egg, and the proliferous activities of the sponge.

After some years of frequent trips to the bottom of the bay in a diving helmet, with the accompanying aching shoulders, water-wrinkled hands, and chilled bones, the author, with the help of friends, built and successfully used a simple "bentharium" that permitted dry and longer excursions under water. The accounts of these activities take their proper proportion in importance and space in the book, and are refreshingly free from attractive blondes recording dramatic messages over phones, and new species of passing fish.

The last chapter, entitled "Compensation," is a rewarding and not-too-heavy philosophical summation of the balance of nature and the protoplasmic hereafter as demonstrated by the continuous production of offspring in nature.

R. TUCKER ABBOTT

U. S. National Museum
Washington, D. C.

FULLER'S BOTANY

The Plant World: A Text in College Botany. (Rev. ed.) Harry J. Fuller. 769 pp. Illus. $4.75. Holt, New York. 1951.

ALTHOUGH the author has enlarged this general botany textbook in the process of revision, it still has the increasingly rare merit of being somewhat less than overwhelming in sheer physical bulk.

The book is divided in the traditional way into a first part on the structure, physiology, and reproduction of flowering plants, comprising somewhat more than half the volume; a second part devoted to the characteristics of the various members of the plant kingdom; and a third, briefer part on "the distribution of plants in time and space"—i.e., evolution and ecology. The enlargement is accounted for briefly by the inclusion of a separate chapter on soil, a section on hybrid corn, a separate expanded chapter on bacteria, and a general expansion of the treatment of the plant kingdom. The last is, according to the author's preface, in response to demands by users of the book. The essential details of a number of life histories are included, and the modern classification into Thallophyta, Embryophyta, Tracheophyta, etc., is followed.

Chapter summaries are retained and lists of suggested readings and study questions have been added to each chapter. An increase in the number of section and paragraph headings and the use of boldface type for these increase the utility and emphasize the structural outline of the text.

The book is abundantly illustrated with many excellent photographs, as well as line drawings. The former, especially, are both striking and instructive. A student who could explain all the illustrations with their labels and legends would have a fairly adequate grasp of the subject matter, even if he did not read the text carefully!

The revisions, apart from the enlargement of the section on the plant kingdom, are all in the direction of increasing the student's awareness and understanding of what goes on in the world around him. Practical applications are discussed freely, sometimes in sections set apart and labeled as such, as in the case of grafting and pruning, sometimes presented as a natural extension and illustration of facts and theories, as in the case of pelleting of seeds, food preservation by sugar or salting, or hybrid corn. Student interest and curiosity are also encouraged by the inclusion of a brief appendix giving information and references on hydroponics and on the production of seedless fruit by means of plant hormones.

Students' ideas of the personality of botanists should be favorably influenced by the substitution of a drawing of Linnaeus as a personable young man in Lapland dress in place of the photograph of a very stony-looking bust used in the first edition.

Any botanist will no doubt find details with which to quarrel in the book. This reviewer singles out only two drawings concerning fern gametophytes: one a traditional type view of a mature prothallus with a neatly rounded base that gives no indication that the structure has developed from a single cell rather than materializing fully formed; the other showing an antheridium releasing sperms, which indicates that the artist, at least, has never watched the trap-door operation of the lid cell.

It seems to the reviewer rather feeble to confront the student, who presumably is already committed to the course, with the question "Why study botany?" That question should be answered during the course of study by the subject matter itself as presented in the book in his hand: a knowledge of plants can substantially increase one's capacity to see and understand and enjoy the world in which he lives.

BETTY F. THOMSON

Department of Botany
Connecticut College

CLASSICAL PHYSICS

History of the Theories of Aether and Electricity. (Rev. ed.) Sir Edmund Whittaker. xiv + 434 pp. 3/26. Thomas Nelson & Sons, London. 1951.

IN 1910 Sir Edmund Whittaker published a book entitled *A History of the Theories of Aether and Electricity from the age of Descartes to the close of the 19th century.* This book was reviewed in *Nature,* May 28, 1911. The first half of the twentieth century was a very creative period in physics, and as the years went by Sir Edmund increasingly felt the need of supplementing his book by a second volume bringing the picture of physics up to date. He also felt the advisability of rewriting certain parts of the 1910 book and incorporating additional material. The book now under review is this rewritten version of the 1910 book. In his preface Sir Edmund promises a second volume in which the story will be continued to the present time.

The first chapter of the book under review covers the development of the aether theory from the time of Aristotle to the death of Newton. The term *aether* in ancient cosmology was sometimes used in the sense of the blue sky which occupied distant celestial regions; and when the notion of a medium filling the interplanetary void was introduced *aether* was the obvious word to use for it. Descartes (a younger contemporary of Galileo) was the first to bring the aether into science by postulating that it had mechanical properties. So far as the theory of light was concerned, Descartes' conceptions rapidly displaced those that had been current in the Middle Ages. "Give me matter and motion," he cried, "and I will construct the universe." Descartes was the originator of the mechanical philosophy—i.e., of the doctrine that the external inanimate world may for scientific purposes be regarded as an automatic mechanism, and that it is possible and desirable to imagine a mechanical model of every physical phenomenon.

The many defects of Descartes' method led to the rejection of almost all his theories in less than a century. Hooke, Newton, and Huygens were among the early

contributors to the rapidly changing theory of the aether. The development of this theory did not stop with the death of Newton, but continued up to the end of the nineteenth century, the end of the period covered by the book under review. We may look forward with pleasant expectation to Sir Edmund's discussion of relativity in his promised second volume.

Electric and magnetic science underwent a development similar to that of the aether. The ancients were acquainted with the curious properties possessed by two minerals—amber and magnetic iron ore. Magnetism was one of the few sciences that made any progress during the Middle Ages; but with the Renaissance both magnetism and electricity made rapid advances. Faraday and Maxwell are each given the distinction of a separate chapter by the author, and "The Followers of Maxwell" are all discussed in one chapter.

The closing years of the nineteenth century brought forth the discoveries of X-rays and electrons, which, by the wide field of research they opened up, ended the period of classical physics. Sir Edmund closes his book with a discussion of the electronic theory of metals and thermionics.

Such a book cannot be written without considerable mathematics. To economize space the author uses vector notation and gives a memorandum explaining this notation; but the mathematical portions of the book have the premises and conclusions so clearly stated that a reader who omits the intervening mathematics will still get an excellent picture of the historical development of the theories of aether and electricity.

PAUL R. HEYL

Washington, D. C.

ENTOMOLOGY, GENERAL AND SPECIALIZED

Insect Natural History. A. D. Imms. xviii + 317 pp. Illus. $5.00. Blakiston, Philadelphia. 1951.

THE late Dr. A. D. Imms was for many years a reader in entomology at Cambridge University and chief entomologist at the Rothamsted Experimental Station. His wide experience and ability have long been reflected in his *General Textbook of Entomology,* considered by many entomologists the leading general text in the English language. The book here reviewed first appeared in England in 1947 as Volume 8 of the "New Naturalist" series. Thus its publication in America bears testimony to the fine reputation it has earned and its permanent value.

The text is beautifully written, well adapted for readers who do not have an extensive vocabulary. The illustrations, especially those in color, are excellent. It is refreshing to read a book written for the general reader which not only is interesting and clearly written, but which also is rich in subject matter and authoritatively prepared throughout. The thirteen chapters cover the following subjects: Insect Structure and Transformations; How Insects Are Classified and Named; On Wings and Flight; The Senses and Other Attributes; Concerning Feeding Habits (2 chapters); Insects and Biological Control; On Galls; On Ways and Means of Protection; The Phenomenon of Reproduction; Aquatic Insect Life; Gregariousness and Social Life (2 chapters).

As originally prepared, primarily for British readers, this book has no obvious faults, but Americans wishing to use it for reference or teaching should realize that a great majority of the species discussed and illustrated inhabit the British Isles. This in no way detracts from the treatment of principles, but the examples cited seldom occur in America, although in many cases closely related and rather comparable species are found here. Some common names of groups are typically British rather than American, such as "shield-bugs" instead of "stink-bugs;" and praying mantids are not even mentioned, probably because they do not occur in England. With due allowances made for certain handicaps of this sort, American teachers will find the book excellent for supplemental reading by students, or as a reference in preparing lectures on special subjects such as those represented by the various chapters. Biology teachers should find this a useful reference when treating many of the principles shown by insects. All in all, Dr. Imms' book deserves an honored place on our shelves.

Embryology of the Viviparous Insects. Harold R. Hagan. xiv + 472 pp. Illus. $6.50. Ronald Press, New York. 1951.

MOST entomologists have had little contact with viviparous insects since they learned as students about the occurrence of viviparity in such insects as *Arixenia, Hemimerus, Miastor, Micromalthus,* and the Hippoboscidae, unless perhaps, they have worked with certain aphids that produce living young. Moreover, previous attempts to develop a classification of viviparous insects have not been very successful. Now there is provided the groundwork for an orderly understanding of viviparity in its several modifications and an appraisal of the basic meaning of viviparity and its probable future in insect evolution. With the appearance of this book, therefore, the subject may be said to have come of age. It is not surprising that for the work Dr. Hagan, who is an associate professor of biology at the College of the City of New York, was awarded a prize by the New York Academy of Sciences. He is no beginner in the field, nor is the book a mere compilation. His researches in insect embryology extend back some thirty-five years, and the book contains much new material. His own plan for grouping the different types of insect viviparity is essentially the same as the one that has been favorably received both here and abroad since he proposed it twenty years ago.

Each order containing viviparous forms (thirteen, if Homoptera and Strepsiptera are considered distinct orders) is reviewed, with special attention to the embryological details of various examples. No ametabolous insects have been found to exhibit the phenomenon. Much of the book is highly technical and of interest primarily to a person with considerable background in embryology. Within each order, however, basic egg development is discussed so clearly and in sufficiently general terms that

a taxonomist anxious to learn the peculiarities of his own group may profit from using the book as a reference text. Students familiar with Berlese's views on the meaning of metamorphosis will be interested in the broader aspects which Hagan has discussed clearly and thoughtfully.

In the introduction some fundamental concepts and terms such as "ovoviviparity" and "paedogenesis" are defined. The last of fifteen chapters is an appraisal of viviparity with the discussion grouped under the following headings: modifications associated with viviparity; the problem of fertilization; the causes of viviparity; evolutionary trends toward viviparity; maternal solicitude; the future of viviparity. The introduction and the last chapter are especially commended to the general entomologist by this reviewer. Each chapter is well documented with references, and the book is supported by a bibliography of some 500 publications. This appears to be one of the truly fine books of recent years, and entomologists may thank Dr. Hagan for adding it to their working tools.

ASHLEY B. GURNEY
Bureau of Entomology and Plant Quarantine
U. S. Department of Agriculture
Washington, D. C.

MEASURING THE I. Q.

Intelligence and Cultural Differences. Kenneth Eells, Allison Davis, Robert J. Havighurst, Virgil E. Herrick, and Ralph W. Tyler. xii + 388 pp. Illus. $5.00. University of Chicago Press, Chicago. 1951.

CHILDREN from higher socioeconomic groups make higher average scores on intelligence and academic aptitude tests than do children from lower socioeconomic groups. This long-established fact has frequently been interpreted to mean that persons of higher intelligence tend to occupy higher positions, with higher salaries, prestige, and opportunities, and that they tend to pass their greater ability on to their offspring. Eells and his co-authors propose the alternative argument:

> If (*a*) the children from different social-status levels have different kinds of experiences and have experiences with different kinds of material, and if (*b*) the intelligence tests contain a disproportionate amount of material drawn from the cultural experiences with which pupils from the higher social-status levels are more familiar, one would expect (*c*) that children from the higher social-status levels would show higher I.Q.'s than those from the lower levels. This argument tends to conclude that the observed differences in pupil I.Q.'s are artifacts dependent upon the specific content of the test items and do not reflect accurately any important underlying ability in the pupils (4).

This argument is sometimes set up as but one of several alternative hypotheses for exploration, but usually it seems to be assumed as the explanation which the authors hope to prove.

Eells administered several standard tests to the nine-, ten-, thirteen-, and fourteen-year-old pupils in the Rockford, Illinois, schools. An index of social status was obtained for each pupil. High- and low-status pupils were compared on individual items, as well as on the tests as wholes. In addition, Eells made detailed item analyses of 315 items to determine what kinds of items differentiate most clearly between high- and low-status children.

In addition to the expected higher scores of the high-status children, major findings were: "Mean status differences are largest for verbal and smallest for picture, geometric-design, and stylized-drawing items" (54); "practically all the items showing unusually large status differences are verbal in symbolism" (54); "a number of the differences [in distribution of errors] can be accounted for in terms of status differences in opportunity for familiarity with certain objects, words, or processes" (55); and, "status differences in I. Q. terms appear to be . . . larger for the thirteen- and fourteen-year-old pupils than for the nine- and ten-year-old pupils" (56).

The interpretation of these findings raises the fundamental question: What are so-called intelligence tests intended to measure? How best to define intelligence has never been settled satisfactorily. Consequently many test builders construct tests for predicting academic success, job skills, aptitude for learning this or learning that, and call their tests *aptitude tests* rather than *intelligence tests*. Their problem is simply to select those items which predict some agreed-upon criterion most effectively without regard to social-status distinctions. The authors recognize this possibility, but are not satisfied with it, despite its practical usefulness and wide acceptance.

Instead, they seem to assume that most test builders are attempting to measure an underlying ability, probably largely genetic in character, which is as far as is reasonably possible independent of differences in opportunities to learn. The actual achievement of such a goal is impossible, as both the authors and nearly everyone else recognizes. The monograph provides additional evidence, however, on the degree to which the seven tests used in the study fail even to approximate it.

Most of the monograph consists of a report of Eell's doctoral dissertation. His work was well planned, great in amount, and obviously carefully done and analyzed. It will have less of an audience than it merits because of the form in which it is presented. The book suffers from too many authors, too much repetition, and too little of the basic data. Part I (six chapters by Eells and four members of his dissertation committee) takes up the problems of cultural bias in test performance, states the authors' position, and anticipates the major results. Part II (three chapters by Eells) is a good summary of the problems of cultural bias in test performance, of the results obtained, and of the implications of those results. Part III (14 chapters by Eells) gives in greater detail the problems of cultural bias in test performance, the way in which the study was conducted, selected samples of the data, and the author's interpretations of those data. As a consequence of this organization, the same problems and points of view are presented with quite unnecessary frequency. For most readers,

Part II will give an adequate account of the work. Those who are particularly interested in test construction problems would gladly have sacrificed some of the repeated statements concerning the social-status differences in order to have had all of the basic data presented.

DAEL WOLFLE

Commission on Human Resources and Advanced Training

VERTEBRATES AND INVERTEBRATES

The Life of the Spider. John Crompton. xii + 254 pp. Illus. $3.00. Houghton Mifflin, Boston. 1951.

THIS book, first published in England in 1950, has had an introduction by Alexander Petrunkevitch and numerous footnotes added to the present edition. It is a popular account of the doings of a few members of one of the commonest, and at the same time least understood, groups of animals. We have spiders about us all the time almost anywhere we may go. Perhaps the reason most of us know almost nothing about spiders is that most people kill them as soon as possible, which allows no time to discover the interesting things they do. The best way to start to know something about spiders is to read Crompton's book.

As he says, all spiders fall roughly into five groups: the web weavers, the wolf spiders, the jumping spiders, the crab spiders, and the large hairy spiders, which in this country are usually called tarantulas. The five groups are well represented in the United States, and the reader will find generalized accounts of them in the first five chapters, followed by discussions of habits or conditions common to all the groups, such as ballooning, enemies, means of defense, courtship, and intelligence. A chapter is given to the water spiders, and one to human reactions to spiders. Right in the middle of the book is a most readable account of the life of Fabre, pioneer in the field of popular science. The whole story is told in a delightful and fascinating manner, although in spots the author is perhaps a bit too imaginative in his selection of words. For instance, no male spider ever raped a female. "Rape" implies the existence of a moral code, and there is no evidence that spiders have any morals at all.

E. A. CHAPIN

Division of Insects
U. S. National Museum
Washington, D. C.

The Invertebrates: The Pseudocoelomate Bilateria: Acanthocephala, Aschelminthes, and Entoprocta, Vol. III. Libbie Henrietta Hyman. vii + 572 pp., 223 figures. $9.00. McGraw-Hill, New York. 1951.

THE volume is subdivided in three main chapters, each treating one of the pseudocoelomate phyla recognized, the Acanthocephala, the Aschelminthes, and the Entoprocta. The aspect of this treatment of most interest to the general zoologist is the formulation of the phylum Aschelminthes, to include Classes Rotifera, Gastrotricha, Kinorhyncha, and Priapulida. As in all cases where major debatable zoological issues are involved, the author has arrived at the presented stand primarily by compiling the consensus of published information modified by considered critical subjective evaluation. Since necessarily personal preferences and choices must be concerned at the level of generalization under consideration, the background features of her position are clearly stated and alternative possibilities of classification pointed out.

Each phylum is descriptively presented in a treatment which includes historical background, characters of phylum, classification of the phylum, morphology, development, ecology and physiology, and phylogenetic considerations. The high degree of differentiation of the aschelminth classes is reflected by presentation of comparable extended treatment under each class heading. The bibliography is distributed to terminate each of the three main chapters, and totals 54 pages. This extensive documentation is clear evidence of the unparalleled array of information which has been coordinated into an integrated and consistently generalized characterization. Repeated reference to the volumes of the series overwhelmingly demonstrates the reliability of the details. Probably of even more difficult accomplishment, but equally well achieved, is the remarkable synthesis of the abstracted essentials of the groups to provide a considered, integrated concept of each as a whole. The product does not at all resemble a simple compilation of minutiae, but conveys a profound sense of zoological and biological reality.

PAUL L. ILLG

Division of Marine Invertebrates
U. S. National Museum
Washington, D. C.

Animal Evolution. A Study of Recent Views of its Causes. G. S. Carter. xv + 368 pp. Illus. $4.50. Sidgwick and Jackson, London; Macmillan, New York. 1951.

THIS attempt to bring the record up to date, to draw together the old and familiar data and interpret them in the light of newer investigations, is directed at the student and the zoologist whose duties prevent them from detailed study of the more technical recent literature. Carter feels that the time is ripe for a sounder evaluation of natural selection in its post-Darwinian form, and considers the topic from two angles: the practical statements of evolutionary evidence in biological facts, and the analysis of the whole theory of evolution —microevolution, macro- and megaevolution, preadaptation, discernible trends, and rates of evolution. Strong emphasis is placed on the need for more complete life-history information, and caution is called for in many places to avoid incorrect conclusions regarding extreme specializations in form and function. "Most . . . objections arise from failure in one way or another to take a broad enough view of evolution, failure to realize that it is the whole life and activities of an animal that evolve together and that all aspects of its evolution are interdependent." With a bibliography of 340 references and an excellent index, Carter provides a solid base for discussion and interest in future investigations.

Introduced Mammals of New Zealand. An Ecological and Economic Survey. K. A. Wodzicki. x + 255 pp. Illus. 12/6. Department of Scientific and Industrial Research, Wellington, N. Z. 1950.

THIS, according to the foreword by F. R. Callaghan, secretary of the governmental department that published the book, is the first extensive animal ecology investigation made in New Zealand. It is a great pity that the study came so late, and has to reflect such a myopic wildlife policy as has existed in all but recent years. Wodzicki confines his pages largely to statistics of when species were introduced, how they reproduced, what economic damage they did in contrast with what economic return they brought, and a discussion of present attempts to control devastation. More than half the mammals and birds were introduced from England by colonists who sought to develop a familiar food supply and a replica of European fauna in songbirds and game. Australia contributed the opossum and wallaby, Polynesia a native dog (now extinct) and the Maori rat, Asia a number of deer, Europe the chamois, and America more deer. Of these 29 have become "problem animals," which have wiped out a major part of the native wildlife and are now causing enough damage to warrant "future research designed to improve their control." The need for further natural history information is emphasized. There is a detailed table of contents but no index.

Union Bay: The Life of a City Marsh. Harry W. Higman and Earl J. Larrison. ix + 315 pp. Illus. $4.00. University of Washington Press, Seattle. 1951.

THIS book, written jointly but in the first person singular, gives a straightforward account of many leisurely canoe trips through a marsh which "lies along the eastern portion of the University of Washington campus and occupies a part of pouch-shaped Union Bay." The effect of man on the birds and mammals, of the animals on man's property, are contrasted. The overall effect is peaceful, though with a realization that sooner or later the human beings who surround Union Bay, who use it for fishing or speedboating, will eventually obliterate the marsh and its inhabitants. Except for a few Northwestern species mentioned, the treatment applies broadly to any marsh in temperate America, and a quiet appreciation develops for the ecological interrelationships there. The book is written in narrative form and has not been provided with an index.

Zoogeography of the Land and Inland Waters. L. F. de Beaufort. viii + 208 pp. Illus. $5.00. Sidgwick and Jackson, London; Macmillan, New York. 1951.

DE BEAUFORT has provided an extremely useful reference work in small form for those zoologists who seek a careful discussion of the geographic distribution of the vertebrates on land masses from island to continental size. A small number of invertebrates receive attention, but omission of such interesting forms as *Peripatus* indicates either deliberate limitation of subject matter or a lack of familiarity with the large literature on nonvertebrates. Preoccupation with local distribution might be assumed in seeing almost a third of the analysis of the Holarctic region given over to the British Isles alone, but the interesting and clear account of the problems in Madagascar and in the areas adjacent to Wallace's Line amply reward the reader who reaches the later chapters. The terms "Neogaea" for the Neotropical and "Notogaea" for the Australian, New Zealand, and related island realms emphasize a confusing terminology that has been avoided by many followers of Sclater's original separation of zoogeographical areas. There are a good bibliography and an excellent index.

LORUS J. and MARGERY J. MILNE
Department of Zoology
University of New Hampshire

THEORY-BUILDING

The Social System. Talcott Parsons. xviii + 575 pp. $6.00. Free Press, Glencoe, Ill. 1951.

THE era of the great system builders in social thought is over, many American sociologists are fond of remarking, and such indeed is the prevailing opinion in sociological circles today. The emphasis is on specialized research, and where theory is taught the approach is eclectic and historical, with the concepts of such men as Comte and Spencer presented largely as historical curiosities.

The last of the great system builders was the Italian sociologist Vilfredo Pareto, whose monumental work, *The Mind and Society*, has been called "the swan song" of the era of system builders in social thought. Pareto's work has been a storm center of controversy; attacked by some as reactionary, obsolete, and outmoded, he has been praised and emulated by others.

Pareto's theoretical system has enjoyed wide influence and is not without supporters in this country; it will come as no surprise to many that his system is expounded and elaborated at Harvard University by Talcott Parsons, head of the Department of Human Relations.

The present volume is the latest in a series of works by Parsons, begun in 1937 with the publication of *The Structure of Social Action.* In these books Parsons expounds his theoretical system, founded on the model of Pareto, whose work was "an attempt to construct a system of social theory on the model used in the natural science of mechanics." In revising and expanding the Pareto system, Parsons has deleted much that the Italian master considered crucial and has incorporated fragments from the theories of Durkheim and Weber; in the present volume some Freudian concepts also make their appearance. His work is of a philosophical, nonempirical nature, offered to provide a theoretical framework for integration of the findings of empirical research.

Parsons rejects biopsychological preoccupation with internal functioning of the individual organism and, following Pareto, uses the term "actor" rather than "organism" to designate an individual social unit, disregarding its individual characteristics as irrelevant. An

astronomer sees infinitely distant stars in celestial space as points of light without physical dimension, and Parsons sees human individuals as points of reference in social space, without physical dimension.

The author defines a social system as a plurality of actors interacting with each other in a situation which has at least a physical or environmental aspect. Parsons refers to social systems as "boundary-maintaining systems," explaining that by this he means that they "maintain certain constancies of pattern, whether this constancy be static or moving." Such systems are likened to biological organisms, which he declares are also boundary-making systems. These are empirical constancies, says Parsons; he does not assume any inherent reason why they have to be maintained. The question for science is, *Why* are they maintained?

What features must a social system have in order to maintain its boundaries? Following Pareto, Parsons declares that it must maintain equilibrium. In order to do this, a social system must satisfy the needs of the individual member and at the same time provide for its own needs of minimum stability. It does this by providing for the biological needs of the individual and meeting the conditions for minimum stability of the personality; by providing for minimum motivation for participation, and minimum control over disruptive or deviant behavior.

What are the social atoms and molecules of Parsons' social systems? He does not posit any basic units as empirical entities, but for the purposes of analysis, he recognizes the following four: (1) The Act: the most elementary unit; (2)The Status-Role: the combined structural and functional points of view, serving to articulate the two cross-cutting modes of organization of social systems; (3) The Actor: the organized system of all the statuses and roles referable to him as a social object and as the author of a system of role-activities; (4) The Collectivity: as actor and as object, the collectivity cuts across the individual actor—the particular sectors of the action-systems of individuals are abstracted and treated together.

Parsons' concept of a collectivity is perhaps synonymous with that of the group, already well established in sociological literature. In Parsons' collectivity, members share common value patterns which entail a sense of responsibility and which create solidarity. The actors have common sentiments in support of such value patterns. These sentiments are not ordinarily biologically inherent, but are learned and acquired.

It is at this point that Parsons introduces his concept of *internalization* of cultural values, a concept borrowed from psychoanalysis. The author makes the distinction between external culture ("in books," etc.) and internalized culture. In the process of internalization, the individual incorporates the values and ideals of the culture within his own personality system, and gratification-deprivation is seen as satisfaction or thwarting of the values and goals institutionalized in the culture.

In any scientific explanation of society, one of the problems that must be solved is the identity of motivating force, or social energy. Many concepts have been offered in explanation (e.g., *instincts, wishes, desires, needs,* and *reflexes*), none of which has met with complete approval. The theories they represent have been rejected as committing the errors of reification or tautology, or at best have been accepted only as heuristic aids to further insight and investigation. Pareto used the term "sentiments" and elaborated that sentiments were manifested in "derivations," and carried along in the culture as "residues."

Parsons talks of "need-dispositions," and asserts that the source of energy in social system is the "trend to optimum gratification and avoidance of deprivation." However, he admits that his concept is no better than older theories in explaining the directions involved in social change, saying that for this we must "turn to other features of the total system of action."

This is the old dilemma of hedonism, the pleasure-pain principle. Social systems do not feel pleasure or pain; therefore, the trend to optimization of gratification (pleasure) cannot provide the key to prediction of the direction of change in social systems.

Although social systems do not feel pleasure or pain, they must be functionally integrated, or else their boundaries will disappear—in other words, the pattern will disintegrate, to be destroyed or replaced by another.

Private goals cannot serve as the basis for orientation of collectivities, and will tend to destroy the collectivity if they dominate. Therefore, if there is conflict between the institutionalized values of the collectivity and the private interests of the individual, the collectivity will not be well integrated and will be in danger of disintegration and the destruction of its boundaries. If, however, the values of the collectivity are sufficiently internalized in the individual members, so that the realization of its goals provides gratification for the individual, then the collectivity or social system approaches what might be called an ideal type of integrated system. This, in effect, is what Parsons proposes as the fundamental canon for sociological theory.

One of the criticisms most frequently leveled at Pareto's *Mind and Society* is that it is the most badly organized book ever written. This brings up another point that Pareto and Parsons have in common: Parsons' style of writing is verbose and involved; his book is poorly organized and tedious to read. Much of his difficulty in writing is doubtless due to the fact that he feels compelled to lean over backward to avoid the criticism that his theories emphasize the static, structural point of view, and that therefore they are not dynamic. This causes him to write endlessly almost entirely in terms of form rather than content; it is like attempting to hold a sustained conversation about motion without mentioning physical bodies. Combined with this is a tendency of the author to sprinkle his work with neologisms, or to substitute words like *actor* and *action* for *individual* and *behavior*, to the point where the bewildered reader is in need of a sort of "Parsons dictionary" in order to understand what is being said.

Many of the concepts Parsons presents are already in widespread use in sociology today, but are recognized

elsewhere by the much more familiar labels of current sociological terminology. Parsons' unusual nomenclature is without doubt his most singular characteristic, and the prospects seem to be that if any of it survives his work he will have assuredly made his mark in the realm of sociological theory-building.

ROBERT E. WILLIAMSON

Washington, D. C.

BASIC EARTH SCIENCE

Physical Geography. Arthur N. Strahler. ix + 442 pp. Illus. $6.00. Wiley, New York. 1951.

WORLD WAR II revealed just how abysmal was the lack of geographic knowledge and understanding in the average college graduate in these United States. Since then there has been a healthy interest in the subject, and a growing number of colleges are including courses in the field in their curricula. One of the difficulties has been the lack of basic texts to use with those students who do not expect to continue in the field of earth sciences. Dr. Strahler has produced a textbook that should fill the void in the field of physical geography. This is a book designed for the many students who should have a basic knowledge of the world about them to better understand the field in which they plan to concentrate.

Dr. Strahler has not departed from the well-founded principles of Tarr, Salisbury, and Atwood, but he has brought them up to our present knowledge and points of view. The cooperative effort of author and publisher has produced the most attractive volume at college level that I have seen in years. What strikes me most forcefully is the wealth of illustration, much of it refreshingly new to textbooks and not a little especially prepared for this one. Every illustrative device, lacking color, has been employed. Many of the block diagrams are masterly in their simplicity and clarity.

Along with this excellent graphic demonstration of the principles involved goes a mature, sound text. This is the first time that I have seen any text on physical geography that adequately discusses maps and map-reading. Almost the first quarter of the volume is devoted to this topic. Too often a student flounders through physiography because the instructor has forgotten that map-reading must be learned and mastered as well as word-reading if the student is to appreciate maps, the prime tool of the geographer. The discussion of maps leads smoothly into that of landforms. Here the principles and outline of geomorphology are treated simply and clearly. Lobeck's influence is strong but does not overshadow Strahler's own ideas of sequence and importance. The transition to the third part of the volume is rather abrupt, but once made the text moves smoothly to its conclusion. In this section the problems of weather and climate are unfolded and lead back to the land via soils.

Each of the 28 chapters is developed according to a uniform plan—a prime topic, simply explained and developed, with pertinent details and related phenomena touched upon. Each closes with review questions and, with few exceptions, a group of exercises. The exercises caught my eye as I first leafed through the volume. They answer the prayer of the institution where classes are large or funds are low! Everything needed is in one package. Every map required and all the data needed are there. For only one chapter are the maps not quite adequate—"Landforms Made by Wind." Having just searched some 2,000 map sheets for material for a series of exercises, I know why they are not—cartographically they are well-nigh impossible because of scale.

The volume closes with 17 pages of "References for Further Study." These are the result of much search and even more sorting! The beauty of the brief selected bibliographies for each chapter is that all references will be found in most college libraries—and I'm thinking of the small colleges. Without counting, I should say that the really splendid articles in *Geographical Review* outnumber those in any other publication of its type. I can see many good term papers in these references.

One could wish that there were a little more space devoted to the sea. To be sure, many of the effects of the oceans upon land and climate are introduced into the text at the proper places, but so much new is being discovered in this "last frontier" of geography to fire the imagination of young students that I for one feel its absence in an otherwise almost ideal textbook.

F. MARTIN BROWN

Science Department
Fountain Valley School
Colorado Springs, Colorado

ONTOGENY AND PHYLOGENY OF THE EQUIDAE

Horses. George Gaylord Simpson. xxiv + 247 pp. Illus. $6.50. Oxford University Press, New York. 1951.

READERS of Dr. Simpson's "story of the horse family in the modern world and through sixty million years of geologic history" will find therein confirmation for many fragments of information they have gathered for mental storage through popular science reading over the years, and a wealth of additional facts to fill in gaps in their knowledge. This is not meant to imply that the book answers all questions, or that it is even the last word about horses. It isn't. A much more ponderous tome, which few would read for pleasure, would be needed to satisfy top-ranking experts.

The book contains no revolutionary new discoveries or announcements, no momentous reversals in nomenclatorial familiars, no radical departure from accepted scientific procedures, but it covers the ontogeny and phylogeny of the Equidae as no other popular volume has done. It answers simple questions like: "What is a horse?" "Where can I see fossil horses?" and "How do horses' teeth change?" It also answers more complex ones: "Where did horses come from?" "How much intelligence do horses have?" and "How did horses of another color get that way?"

At the American Museum of Natural History, where Dr. Simpson is chairman of the Department of Paleontology and Geology, as well as dean of the science staff, the past history of the horse has been a favored scientific study for many years. Assembling a large collection of recent and fossil Equidae and meanwhile compiling everything known about this fascinating group of animals was the ambition of the late Henry Fairfield Osborn when the museum's department of mammalian paleontology was first established (1891). The horse program required a large staff of research assistants, librarians, secretaries, and artists. Among those who collected fossil bones and studied them were W. D. Matthew, J. W. Gidley, and Walter Granger. Adam Hermann, Albert Thomson, and Charles Lang concerned themselves with the preparation and mounting of specimens. S. H. Chubb devoted the greater part of his lifetime to preparing skeletons of recent horses. Among benefactors lending substantial financial support to the program was William C. Whitney.

The result has been a steady stream of technical papers and the amassing of a great volume of portfolios containing notes, sketches, and paintings, and many cabinet drawers of index cards. About 1913 a popular booklet was published on the *Evolution of the Horse*, by Matthew and Chubb. It proved so popular with instructors, students, and museum visitors that it was kept in print for many years, with only minor changes.

"The present book," the author says, "is an effort to carry out the departmental plan of sixty years' standing but to do so on a scale incomparably more modest than was anticipated by Osborn and his staff. This book is, indeed, intended to be a 'full history of the horse,' as far as such a history can now be written."

Part One is devoted to modern living horses, their place among other members of the animal kingdom, their recent history, breeds, gaits, color, intelligence, uses, and characteristics. Part Two covers phylogeny—the time-scale of horse history, the forerunners of horses, the little Eocene ancestors, pseudo-horses, early three-toed horses, one-toed horses, and the hunters and hunting of fossil Equidae.

Anticipating a need among students for a readily available chart, or "family tree," and knowing the propensity of youth for inserting such special morsels of knowledge on flyleaves, the publisher has stolen a march on such ambitions and placed an attractive chart in green and white both fore and aft. Thus a thumbnail sketch of horse antiquity is both the first and last tidbit the reader is offered.

Horses will be a compulsory addition to libraries large or small for all who love these useful creatures. Even though the future of *Equus* seems destined to find its greatest expression on the race track and in the pleasure millions still enjoy through equitation, other millions will still know horses more familiarly as farm animals, circus beauties, and cinema silhouettes of the purple sage.

HERBERT B. NICHOLS

U. S. Geological Survey
Washington, D. C.

BRIEFLY REVIEWED

Groups, Leadership and Men. Harold Guetzkow, Ed. Reports on Research Sponsored by the Human Relations and Morale Branch of the Office of Naval Research, 1945–1950. ix + 293 pp. Illus. $5.00. Rutgers University Press, New Brunswick, N. J. 1951.

THIS book is the result of a conference held in 1950 under the auspices of the Advisory Panel of the Human Relations and Morale Branch of the Office of Naval Research. At this conference various individual contractors, engaged in basic research in human relations for the ONR, reported upon the current status of their research programs. These reports, revised for publication, make up the content of the book.

Some twenty-odd papers are reported, and it is impossible to give any detailed discussion of each or to single out individual contributors. The papers have been grouped by the editor, however, into three general areas of research, and these may be mentioned. One of the areas deals with research on group behavior (ten papers), another with research on leadership (four papers), and one with research on individual behavior (six papers).

The research reports are introduced by way of a brief history of the Advisory Panel, its functions, and objectives, from its organization in 1946 to date. Then, after the final research report has been presented, an interesting overview of the conference and of some of the controversies raised by the research reports is provided. A concluding paper deals with the military applications of human relations research.

Although some effort has been made to keep the reporting on a level for the general reader (a glossary of some of the technical terms used has been included), the papers vary significantly in this respect. Some of them, for example, require a fair degree of sophistication in statistical methods, and others demand a familiarity with particularized psychological knowledge.

Since most of the research reports are by technically trained psychologists, and this is reflected in the writing, the book should be of major interest to others with similar training who want to know something of the nature of the current research sponsored by ONR in human relations.

ALLEN L. EDWARDS

Department of Psychology
The University of Washington

Annual Review of Physical Chemistry, Vol. 2. G. K. Rollefson, Ed. ix + 462 pp. Illus. $6.00. Annual Reviews, Inc., Stanford, Calif. 1951.

JUDGING from agreement of Volumes 1 and 2 in tables of contents, there are eleven topics "common to textbooks in physical chemistry." They are: thermodynamics, heterogeneous equilibria, solutions of electrolytes, solutions of nonelectrolytes, radioactivity, radiation chemistry, spectroscopy, molecular structure, catalysis, photochemistry, and colloid chemistry. Nine new and different topics appear in Volume 2 in place of seven

omitted from Volume 1. Three of the new items are the subject of special comment in the volume's preface. All three are more or less expansions from others in the list of eleven, and they are: microwave spectroscopy, isotopes, and ion exchange. One topic, photosynthesis, is a bit unexpected in a volume on physical chemistry. This spread into the domain of other sciences is further exhibited by a chapter on quantum theory.

Since eleven topics are continuations of those from Volume 1 and are concerned with work done during 1950, one would expect that would reduce the total page offerings of Volume 2. Such is not the case, however, for an inventory of this volume finds some seventy more pages, 100 more citations in the bibliography, and more than 500 more subtopics in the general index.

Volume 3, with twenty-one topics in its table, will include the eleven "textbook" topics and four of the Volume 2 additions. This forecast is found on page vii of the volume under review.

B. Clifford Hendricks

Longview, Washington

Punched Cards. Robert S. Casey and James W. Perry, Eds. viii + 506 pp. Illus. $10.00. Reinhold, New York. 1951.

THIS book is a compilation, having no less than 36 authors, including the editors. Its function is to describe the use of punched cards in receiving coded information for mechanical sorting, tabulating, totaling, and calculating. There are four main divisions. The first includes an introduction on fundamentals, a treatment of hand-sorted cards and their operation, and a chapter on machine-sorted cards describing cards and machines commercially available. A brief account of some developments in electronic computation is included.

The second division is one of "case-history" accounts. The third includes practical suggestions on coding and its mathematical possibilities. Several possibilities in application are shown, similar to some in the second division. A chapter on correlation analysis develops use of punched cards in accumulating sums of products, reducing labor when there is a large number of cases. A final chapter discusses analytical applications and mathematical relations. The fourth division sets out potential future uses in studying scientific literature, and is followed by a bibliography of about 300 titles (other references also appear in the text) and subject and author indices.

The applications shown include condensation and rapid use of files, chemical and physical classification of compounds, patent searching, bibliographical work, use of medical case records, and recording of industrial operations. The widespread present use of such methods in accountancy is not stressed. Numerous pictures and illustrative examples are provided, and coding is described for a number of cases.

An interesting feature is the sketch of the work of each author preceding his contribution. The authors include workers in industry, science, medicine, education, libraries, etc., with the first group predominating. The list does not include ranking figures in the field of statistical analysis.

Punched Cards does not go far into recent advances in extremely rapid calculation, nor into present uses of punched cards in analyzing experimental and survey data. Outlining could be improved. The book will be useful, however, to those who wish to become acquainted with punched-card techniques, and the time-saving in analysis they make possible.

F. M. Wadley

Department of the Navy

Insect Resistance in Crop Plants. Reginald H. Painter. xi + 520 pp. Illus. $8.50. Macmillan, New York. 1951.

ALL entomologists, plant breeders, agronomists, horticulturists, and plant pathologists should be familiar with the contents of this book. It is a well-written and comprehensive treatment of this very important subject. Where resistance to insect attack can be found and utilized it is the ideal method of control because it does not involve the expense and trouble of applying insecticides or changing cultural procedures. As the author and others have shown, resistance in varying degrees has been found in a surprisingly large number and variety of plant species to one or more of the insects that attack them. Dr. Painter has had a long and fruitful experience in the discovery, character, and use of insect resistance in crop plants and has exhaustively reviewed, recorded, and discussed the many accomplishments of other workers in this field. With this background he has presented a thorough treatment of the different types of resistance and the problems involved in their utilization through genetic methods of plant breeding and crop improvement under natural and artificial exposure to infestation. Not only has he produced an authoritative treatise on all phases of the subject but he has also included lists of the more important references at the end of each chapter and a supplementary bibliography at the end of the book. As the author says in his preface, "The general subject of insect resistance is not indexed either in *Biological Abstracts* or in the *Review of Applied Entomology.*" This book will therefore be an invaluable source of information for all investigators, teachers, and students concerned with the subject.

C. M. Packard

Washington, D. C.

THE DISCOVERY OF THE CAUSE OF THE ITCH

IN HER interesting article on "Helminths in History," which appeared in the June 1951 issue of THE SCIENTIFIC MONTHLY, the author, Eileen E. Stewart, unfortunately was guilty of a number of errors in her paragraph concerning Francesco Redi and the discovery of the cause of the itch, otherwise known as scabies.

To begin with, it simply is not true that Redi "discovered the cause of itch." In the second place, whatever "very practical contribution to the welfare of the human race" Redi made in connection with the itch, it was not "early in his career," but in 1687, when he was sixty-one years old. Redi died at seventy-one.

In truth, the discovery of the cause of scabies was made jointly by a twenty-four-year-old physician Giovan Cosimo Bonomo, and his fifty-year-old friend Diacinto Cestoni, a naturalist and pharmacist. The discovery was communicated to Redi on June 20, 1687, in a letter written to him by Bonomo. Redi's "contribution," if we may call it such, consisted in publishing the letter, after having made many editorial changes therein, in pamphlet form, on July 18, 1687. Included therewith were four figures (drawn by the artist Colonello); one represents the dorsal and another the ventral aspect of the female itch mite, the other two are figures of an ovum of the mite.

Mrs. Stewart's statement that the discovery of the cause of scabies "lay in a library for the next 150 years while *Homo sapiens* scratched his way about the world" is amusing, but it is inaccurate and misleading. As a matter of fact, Redi, who most creditably fully realized the significance of the discovery, lost very little time (only twenty-nine days) in calling the attention of the scientific world thereto, in the form of the aforementioned pamphlet.

It is true that Bonomo's *holograph* letter to Redi lay forgotten in a library at Arezzo, Italy, until it was discovered there in 1925 by Professor Alberto Razzauti. However, the published version of that letter was from time to time republished during the following 150 years in Italian and a number of other languages, including Latin, German, and English. What was seemingly *lost* to the scientific (and particularly the medical) world during that period (147 years, to be exact) was the itch mite itself. Not until August 13, 1834, was the mite of scabies "rediscovered"—by a Corsican medical student named Simon François Renucci, in the clinic of Professor Alibert at the Hôpital St. Louis, in Paris.

REUBEN FRIEDMAN, M. D.

Philadelphia

MATHEMATICAL PECULIARITIES, CONTINUED

I ENJOYED reading John Pierce's article on the Fibonacci series in the October SCIENTIFIC MONTHLY.

There is another situation, long familiar to geneticists but not often mentioned in discussions of the series, in which the Fibonacci numbers arise. In 1914 Fish and Jennings gave expressions for the proportion of heterozygous gene loci with successive generations of brother-sister matings. The amount of heterozygosity in successive generations, expressed as a fraction of the initial value, is 2/2, 3/4, 5/8, 8/16, 13/32, 21/64, etc. The numbers in the numerators are the familiar Fibonacci numbers.

Incidentally, one can go Fibonacci one better and define a series in which each term is the sum of the *three* preceding terms. Sewall Wright showed in 1921 that successive generations of double-cousin matings lead to a set of fractions with such a series in the numerators. With quadruple second cousins the series becomes one in which the terms are made up by adding the four preceding terms. Octuple third cousin matings require the summing of the five preceding terms, and so on.

JAMES F. CROW

Department of Genetics
University of Wisconsin

THE erudition of Messrs. F. C. Ogg and Nathan Jaspen is admirable (LETTERS, *Sci. Monthly*, **73**, 333 [1951]), but to a lay reader it seems fortunate that it was John Crawford Pierce who wrote the article on the Fibonacci series (*Sci. Monthly*, **73**, 224 [1951]).

R. G. SLOANE

Elizabeth, New Jersey